U.S. Army Research Institute
for the Behavioral and Social Sciences

Research Report 1819

FUTURE COMBAT SYSTEMS COMMAND AND CONTROL (FCS C^2) HUMAN FUNCTIONS ASSESSMENT: INTERIM REPORT - EXPERIMENT 3

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February 2004

U.S. Army Research Institute
for the Behavioral and Social Sciences

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REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy) February 2004	2. REPORT TYPE Final	3. DATES COVERED (from. . . to) October 2001-December 2003
4. TITLE AND SUBTITLE Future Combat Systems Command and Control (FCS C^2) Human Functions Assessment: Interim Report - Experiment 3		5a. CONTRACT OR GRANT NUMBER 5b. PROGRAM ELEMENT NUMBER 0602785A
6. AUTHOR(S) Carl W. Lickteig, William R. Sanders, Paula J. Durlach (U.S. Army Research Institute), and Thomas J. Carnahan (Western Kentucky University)		5c. PROJECT NUMBER A790 5d. TASK NUMBER 211 5e. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences ATTN: DAPE-ARI-IK 2423 Morande Street Fort Knox, KY 40121-5620		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences ATTN: DAPE-ARI-IK 5001 Eisenhower Avenue Alexandria, VA 22304-4841		10. MONITOR ACRONYM ARI 11. MONITOR REPORT NUMBER Research Report 1819

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 words)* The Army's ongoing transformation to Future Combat Systems (FCS) requires an unprecedented alliance of humans and machines. Creating an alliance that actually improves, and does not impede, battle command is a human systems integration challenge for FCS and particularly the area of command and control (C^2). To address that challenge, the FCS C^2 program is investigating future battle command concepts at the small unit level. The FCS C^2 effort, led by Defense Advanced Research Projects Agency (DARPA) and Communications Electronics and Engineering Command (CECOM) with a focus on human performance by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), included a series of four command group-in-the-loop experiments from October 2001 to March 2003. This report provides exemplar research methods and findings on human performance from Experiment 3. The human performance findings reported are based on subjective measures and highly detailed objective measures of the command group's verbal and human-computer interactions. Interim conclusions are provided on the following topics: workload, training, automated measures, and human-system integration. In closing, a brief set of sustain and improve recommendations are provided for future research efforts. A companion report provides a more comprehensive assessment of future command group performance across FCS C^2 Experiments 1-4 (Lickteig, Sanders, Durlach, Lussier, & Carnahan, In Preparation).

15. SUBJECT TERMS

Future Combat Systems Command and Control Human-System Integration Training Human Performance

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON (Name and Telephone Number)
16. REPORT	17. ABSTRACT	18. THIS PAGE			
Unclassified	Unclassified	Unclassified	Unlimited	112	Dr. Carl W. Lickteig 502/624-6928

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January 2004

Army Project Number 20262785A790	Personnel Performance and Training Technology

Approved for public release; distribution unlimited

FOREWORD

Historically, Army acquisition research has had difficulty conducting an adequate early assessment of the human dimension in system performance. Human performance research is critical to Future Combat Systems (FCS) because enhanced battle command through advanced command and control (C^2) systems is at the heart of the FCS concept. The FCS C^2 program reflects the proactive research on human performance needed to build the force of the future. Attention to the human dimension underscores the role performed by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) as the Army's primary research organization for Personnel, Training, and Leader Development.

This report describes and documents ARI's work and products, particularly measurement methods and results, as a key member of the Human Performance Team for the FCS C^2 program. The work reported here focused on measuring human performance to understand and address task and training requirements for command groups in future FCS organizations. This report provides exemplar methods and results related to FCS C^2 Experiment 3 that attend to the human dimension of battle command in the future force.

The research reported here reflects ongoing work to address human performance issues by ARI, and especially the Future Battlefield Conditions (FBC) Team of the Armored Forces Research Unit (AFRU). This report supports work package (211) FUTURETRAIN: Techniques and Tools for Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C^4ISR) Training of Future Brigade Combat Team Commanders and Staffs, and supports the Science and Technology Objective (STO) "Methods and Measures of Commander-Centric Training."

Findings from this effort were briefed to the Deputy Chief of Staff for Operations and Training (DCSOPS&T) from the Training and Doctrine Command (TRADOC). Methods and findings from Experiment 3 were provided to the Program Manager (PM) for FCS C^2 as part of ARI's ongoing support to FCS and Army research and development efforts.

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Acting Technical Director

FUTURE COMBAT SYSTEMS COMMAND AND CONTROL (FCS C^2) HUMAN FUNCTIONS ASSESSMENT: INTERIM REPORT - EXPERIMENT 3

EXECUTIVE SUMMARY

Research Requirement:

The U.S. Army's challenging transformation to Future Combat Systems (FCS) entails an unprecedented amalgam of humans and machines, a truly hybrid future force. A pivotal example of the FCS transformation challenge is the requirement that a relatively small command group must be able to command and control (C^2) an interdependent mix of manned and autonomous systems. An ongoing research program called FCS C^2 exemplifies the Army's effort to proactively meet this requirement. To ensure a focus on human performance, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) participates in the FCS C^2 research program. This report provides exemplar research methods and findings on human performance by ARI for Experiment 3 in the FCS C^2 research program.

Procedure:

Primary participants were four Active Duty Lieutenant Colonels who formed a notional FCS command group to more fully explore and develop new command and control paradigms. Experiment 3 lasted two weeks with the first three days dedicated to training and the remaining days to experimental exercises referred to as "runs." The execution phase of each run lasted approximately 60-90 minutes, and was proceeded by a planning phase. Overall, 11 of the 12 runs scheduled for Experiment 3 were completed and analyzed for ARI's assessment of human performance.

Efforts by ARI in support of training and evaluation resulted in the respective use of *deliberate practice* and run *complexity* levels. Design for deliberate practice stressed the repetition of similar runs with feedback to ensure results were based on proficient performance. Run complexity was varied (Medium, High, and Too High) to assess how changes in operational conditions might impact command group performance, and to gauge the performance limits of the proposed Unit Cell organization.

The setting was simulated desert terrain from the National Training Center (NTC) in which the Unit Cell conducted deliberate attack missions against a battalion (minus/plus) to clear passage lanes for a follow-on force. The performance feedback essential to deliberate practice included end-of-day AARs. Design goals were to help participants learn, assess, and refine the new technical skills required to operate their C^2 prototypes and the new tactical skills required to exploit the Unit Cell's progressively automated assets.

Measurement methods for assessing human performance were developed and iteratively refined by ARI across the FCS C^2 experiments to better understand command group performance and to identify training requirements. By Experiment 3, the measurement methods designed and developed by ARI resulted in a relatively reliable and comprehensive set of human performance measures that are fully documented in this report. In fact, a rationale for publishing this Interim Report as an ARI Research Report was to document and transfer these human performance measurement methods to future research efforts.

Subjective measures of human performance obtained participant feedback on multiple research issues including: training, skill proficiency, workload, performance success, teamwork skills, decision making, function and task allocations, prototype effectiveness, and human-system integration.

Objective measures obtained detailed and comprehensive data on the verbal and human-computer interactions (HCI) performed by the command group participants during run planning and execution phases. For selected runs, this analysis included every human-to-human verbal interaction and every human-to-computer manual interaction performed by each member of the command group. Analyses related the relatively micro objective behaviors measured to more meaningful C^2 functions including Plan, See, Move, and Strike.

Automated measures of C^2 performance are needed to improve training and evaluation efforts. For Experiment 3, ARI requested a select set of key automated measures be developed to help assess command group interactions with their C^2 prototypes. Only a small subset of the automated measures requested was developed, however, ARI's efforts to validate these measures by comparing them with manual measures obtained from HCI analysis are reported.

Findings:

The human performance findings reported are based on subjective, objective, and automated measures used by ARI to assess command group performance for Experiment 3. Overall, the body of subjective and particularly objective results obtained on human performance represents an emerging empirical database on command group task and training requirements in small FCS units.

The measurement methods developed by ARI resulted in reliable and meaningful data on humans performing command and control in a notional FCS organization. Such human performance data is needed to understand and improve command group performance, and particularly to address training issues including: task analysis, task allocation, workload, performance assessment, and training requirements. The evaluation framework helped relate relatively micro objective behaviors measured to more meaningful C^2 functions including Plan, See, Move, and Strike. Results on development and validation of automated measures, however, were meager and underscore the unmet requirement to instrument prototype and fielded C^2 systems for more effective and efficient training and evaluation.

The interim conclusions provided focus primarily on workload, training, and human-system integration issues related to FCS command and control for small command groups. In

closing, a small set of sustain and improve recommendations are provided for future research efforts. Notably, more comprehensive research methods and findings on future command group performance are provided in a companion report that addresses FCS C^2 Experiments 1-4 (Lickteig, Sanders, Durlach, Lussier, & Carnahan, In Preparation).

Utilization of Findings:

Methods and findings on human performance from each experiment were provided to the Program Manager (PM) FCS C^2 as part of ARI's ongoing support of FCS and Army research and development efforts. Findings by ARI were briefed to the Deputy Chief of Staff for Operations and Training (DCSOPS&T) from the Training and Doctrine Command (TRADOC). The measurement methods developed by ARI to measure, analyze, and report human performance were documented to facilitate their transfer to future efforts, particularly research on battle command. Training issues identified should guide ARI's Science and Technology Objective (STO) titled "Methods and Measures of Commander-Centric Training" and future FCS training development efforts.

FUTURE COMBAT SYSTEMS COMMAND AND CONTROL (FCS C²) HUMAN FUNCTIONS ASSESSMENT: INTERIM REPORT - EXPERIMENT 3

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FUTURE COMBAT SYSTEMS COMMAND AND CONTROL (FCS C^2) HUMAN FUNCTIONS ASSESSMENT: INTERIM REPORT - EXPERIMENT 3

Introduction

This document was originally prepared as an interim report and provided to the Program Manager (PM) of the Future Combat Systems Command and Control (FCS C^2) program upon completion of Experiment 3. Publication as an ARI Research Report provides exemplar research methods and findings for transfer to future research efforts. To more clearly indicate the human performance documentation available from PM FCS C^2 in ARI's interim reports for Experiments 1-4, only minor editorial changes were made in the publication of this Experiment 3 report. Notably, more comprehensive research methods and findings on future command group performance are provided in a companion report that addresses FCS C^2 Experiments 1-4 (Lickteig, Sanders, Durlach, Lussier & Carnahan, In Preparation).

Purpose

The FCS C^2 program is a joint effort led by the Defense Advanced Research Projects Agencys (DARPA)[a] and U.S. Army Communications–Electronics Command (CECOM) Research and Development Center (RDEC). During October 2001 to March 2003, an iterative series of command-in-the-loop experiments were conducted at Fort Monmouth. As a participating member in this effort, ARI serves primarily on the FCS C^2 Human Performance Team.

The stated purpose of the FCS C^2 program is to test the hypothesis that digitization of current battlefield operating systems enables a new approach to command and control:

> If digitization of current battlefield operating systems can substantially enhance command and control by providing better, more accurate, and timely battlefield data to today's commander and staff for decision making; then a "new" approach to Battle Command and Control, implemented in the form of synthesized/analyzed information presented to the future Unit Cell Commander, will enable him to leverage opportunities by focusing on fewer unknowns, clearly visualizing current and future end states, and dictating the tempo within a variety of environments, while being supported by a significantly reduced staff.

Research Goals

Assessment of human functions in order to improve human-system integration supports the Science and Technology Objective (STO) titled "Methods and Measures of Commander-Centric Training." As part of that STO effort, ARI is assessing the human functions required for command and control of FCS forces equipped with advanced Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C^4ISR) systems.

[a] Definitions for the acronyms used in this report are presented in Appendix A.

The research goals for this effort include developing measures of individual and collective command and control performance to support task allocation, workload estimation, performance assessment, and training requirements. In support of these goals, ARI is conducting a functional analysis of human performance across the series of FCS C^2 experiments. This report presents interim findings on the assessment of human performance based on Experiment 3 of the FCS C^2 program.

The need for a human functions assessment is underscored by the fact that the FCS concept entails an unprecedented alliance of humans and machines at the small unit level. This interdependence is reflected in the FCS concept of a network-centric force composed of modular manned and progressively autonomous platforms with netted communication, sensor, and fire capabilities. The C^2 system prototype for the FCS C^2 program was originally referred to as the Commander's Support Environment (CSE), but is referred to as C^2 prototype in this report. The CSE is a hardware and software system located in the command group's C^2 vehicle. The FCS C^2 prototype includes workstations for each of the command group players—Commander, Battle Space Manager, Information Manager, and Effects Manager—that allow them to command and control their Unit Cell elements (DARPA, 2001). The design of the C^2 prototype must be such that it is able to provide the right information, at the right place, and at the right time, which will enable the command group to fight emerging conditions rather than a predetermined plan.

The functional analysis by ARI was designed to identify and describe the command and control behaviors of the command group for an FCS Unit Cell. Analysis developed detailed descriptions of critical command group functions, including operational definitions and behavioral anchors across both the planning and execution phase of selected runs. For Experiment 3, ARI based the human performance analysis on the following measurement methods: objective measures of verbal interactions; objective measures of human-computer interactions (HCI) with the FCS C^2 prototype, including manual and automated measures of HCI; and, subjective measures obtained in after action reviews, surveys, and interviews.

- Verbal Interactions. Verbal analysis of communications included transcription from audio recordings of all spoken exchanges by members of the command group with one another, with higher headquarters, and with subordinate personnel. A taxonomy of communications was developed as a structural framework for the verbal communications rating scheme. Verbal analysis identified the source and type of communication, C^2 function, subject matter, and time duration.
- Human-Computer Interactions. HCI analysis of player interactions included iterative review of video recordings of command group performance in the C^2 vehicle. A taxonomy of HCI tasks was developed as a structural framework for the HCI rating scheme.
- Automated Measures. A related ARI goal was to promote the development of automated measures of C^2 performance. ARI identified and validated a subset of automated measures developed for Experiment 3 by comparing them with corresponding manual measures.
- Subjective Measures. Responses obtained from command group players in after action reviews, surveys, and interviews addressed multiple research issues including: workload, performance success, effectiveness of the C^2 prototype, function/task allocations among humans and machines, teamwork skills and decision making.

As a complementary effort, ARI-Knox is developing an in-house synthetic C^4ISR task environment for analysis and experimentation directed at improving critical C^2 functions, human-machine task allocation, C^2 system interfaces, and military job design.

Human Functions Assessment. The term "functions" generally refers to groups of related actions that contribute to a larger action to achieve a definite goal or purpose. For Experiment 3's focus at the Unit Cell level, the overall function of command group actions was to command and control the Unit Cell and accomplish the assigned mission. To support the assessment of human functions, a candidate set of subordinate command and control functions was adapted from the FCS C^2 experimental design. The set of C^2 functions used by ARI-Knox as a framework for the analysis of verbal and human-computer interactions follows:

- Plan: Develop, assess, and modify a plan including combat instruction sets provided to robotic elements in response to changing events.
- See: Control and interpret input from a heterogeneous set of advanced sensors to mentally construct an accurate picture of the battlefield in terms of Mission, Enemy, Terrain, Troops Available – Time and Civilians (METT-TC) factors.
- Move: Control the movement and activity of friendly manned and unmanned systems to maintain desired movement rates and formations.
- Strike: Distribute a variety of indirect and direct effects over a set of targets.
- Battle Damage Assessment (BDA): Control and interpret input from a heterogeneous set of advanced sensors to mentally construct an accurate assessment of battle damage.
- Other: Interactions that do not fall in any of the above categories.

To the extent this is a good set of C^2 functions, the actions of the command group during the planning and execution of experimental missions, called runs, can be usefully classified into meaningful C^2 behaviors. This report's assessment of human functions is based on observable behaviors, particularly verbal communications and human-computer interactions, to infer the underlying functions. Some degree of interpretation is necessary in classification, and any behavior needs to be evaluated in context of other behaviors and ongoing mission events in order to infer function correctly.

The method approach taken to assess human functions is to classify elements of behavior, namely verbal interactions and human-computer interactions, into more meaningful command and control functions. As a result, the behaviors and workload demands associated with command and control of a Unit Cell can be assessed.

Research Benefits. A detailed assessment of C^2 functions and workload requirements should support many important FCS decisions related to manpower, personnel, task allocation, materiel, and training requirements. For example, the HCI analysis provides useful estimates on the impact of C^2 prototype design changes introduced in Experiment 3, such as Attack Guidance Matrix (AGM), Quick Fire, and Unit Viewer, on command group performance and Unit Cell effectiveness. A related example, a behavioral taxonomy that relates human-computer interactions to key C^2 functions provides an empirical basis for the development of automated measures of command and control performance. Automated performance measures are needed

for more efficient and effective measurement of, and feedback on, command and control performance.

Method

The design of Experiment 3 required that the players plan and execute essentially the same "See, Move and Strike" mission across 11 experimental runs. The design also allowed experimenters to vary run conditions as a function of METT-TC across Medium, High, and Too High levels of Complexity. The execution portion of each run lasted approximately 60-90 minutes.

Level of Complexity was a key manipulation in Experiment 3, introduced to identify how changes in operational conditions impact command group player performance requirements, and their resulting activities or human functions. It was anticipated that changing run complexity level would change workload and performance. More complete descriptions of the Unit Cell's deliberate attack mission and experimental manipulations of run complexity are provided in the Experiment 3 Interim Report prepared by Northrop Grumman (available from the PM FCS C^2).

- Medium Complexity (Runs 1, 3, 7, and 8) presented an enemy reconnaissance force and defending battalion (minus) with regimental support.
- High Complexity (Runs 2, 5, 9, and 11) presented a larger enemy reconnaissance force and defending battalion (minus) with regimental support compared to the Medium Complexity condition. Runs at this level of Complexity also entailed unexpected "wildcard" events including threat force in the South, school buses carrying "Human Shields."
- Too High Complexity (Runs 4, 6, and 10) presented a larger enemy reconnaissance force and defending battalion (minus) with regimental support compared to the High Complexity condition. Runs at this level of Complexity included unexpected "wildcard" events.

Objective Measures. Prior FCS C^2 experiments had relied too heavily on subjective measures *about* performance rather than direct measures *of* performance, particularly for human performance assessment. As a result, for Experiments 1 and 2 ARI's objective measures of human performance were based primarily on manual reduction of audio and video behaviors from recorded runs. The video records were used to conduct a relatively laborious analysis of the command group's verbal interactions and human-computer interactions with the C^2 prototype, as documented in ARI's Experiment 2 Interim Report (Lickteig, Sanders, Durlach, & Carnahan, 2002). In Appendix I of that report, ARI submitted a "Proposed Automated Measures List for Assessing Human Performance and Workload." As a result, the FCS C^2 program developed and implemented a subset of the automated measures proposed for Experiment 3.

The ARI helped the FCS C^2 program validate the automated measures developed for Experiment 3 by comparing them with a corresponding set of manual measures based on ARI's video analysis of selected runs. Results from that analysis are provided in the Results section. The development and validation of automated measures is an iterative process that requires the collaborative efforts of behavioral, technical, and operational subject matter experts. Moreover, as C^2 features are added and refined corresponding automated measures should be identified, developed and validated. Hence, the iterative cycle of identifying, defining, developing, and

validating automated measures of human performance should extend into Experiment 4 and future FCS development efforts.

Subjective Measures. Realistically, an adequate assessment of human performance requires a balance with direct measures *of* performance and subjective measures *about* performance. Results reported are based on the battery of 10 different subjective measures developed and administered by ARI during Experiment 3.

Human Functions Assessment. The Human Functions Assessment discussed here in the Method section and in the following Results section are organized in the following manner:

- Verbal Interactions (Runs 10 and 11).
- Human-Computer Interactions (Run 10).
- Automated Measures Development and Validation (Run 10).
- Subjective Measures (Runs 1-11).

Verbal Interactions

Methods for collection and analysis of verbal behavior from Experiment 3 are described in this section. As overview, the methods for collection were similar to those used for Experiment 2. Methods for analysis, however, included method refinements designed to provide a more comprehensive and meaningful assessment of the verbal communications used to command and control the Unit Cell. The two primary verbal method refinements for Experiment 3 are referred to as Valence and Command Considerations, described in more detail later in this section. Valence ratings were assigned to verbal behaviors to distinguish communications conveying positive versus negative status on accomplishing basic C^2 functions and tasks. Command Consideration classifications were made on verbal behaviors to better identify how participant communications related to key cognitive requirements considered fundamental to the art of battle command.

Collection methods were based on a form of Verbal Protocol Analysis (Ericsson & Simon, 1984, 1993) used in prior FCS C^2 experiments. In essence, participants were encouraged to "think out loud" during the planning and execution phases of each run. Audio/video recordings from selected runs were used to collect the primary participants verbal communications with: one another in the C^2 vehicle (Within Cell); higher echelon, the Blue Team (Black/Blue); subordinate driver and gunner in the C^2 vehicle (Black/ Subordinate); and, supporting personnel including technical assistants (Other). Communications were reviewed and transcribed in conjunction with a quadraplex video from over-the-shoulder cameras behind each primary participant. This quad video image of the four primary participants in the command group greatly assisted verbal transcription and coding, such as identifying the Source of each communication.

The analysis of verbal communications was limited to the final two runs of Experiment 3, Run 10 (Too High Complexity) and Run 11 (High Complexity). Verbal analysis of all 11 runs was not attempted due to the extensive time and labor required to transcribe, chunk, and rate all communications during planning and execution phases. Rationales for selecting the final runs

were to ensure a more stable experimental environment, and more proficient performance by the command group due to the deliberate practice design of the experiment.

In coding of verbal data, there is often a trade-off between extracting the cognitive processes of the speakers in a meaningful manner versus achieving inter-coder reliability. Chunking and classifying communications into meaningful categories often requires a degree of interpretation and context that tends to broaden the scope of disagreement between coders. If different coders fail to agree, then one must question the reliability of the results. One way to increase inter-coder agreement is to consider smaller chunks or samples of verbal data tin order to narrow the range of interpretation. The ARI used this approach, smaller verbal chunks, during Experiment 2 and achieved average inter-coder agreement across coding categories of 93.2%. Based on that success, smaller verbal chunks were also used to analyze the verbal communications for Experiment 3.

Initially, all verbal communications from Runs 10 and 11 were converted to written transcripts that were appended with data on source and time of communication. These transcripts were subsequently "chunked." That is, the flow of communication was blocked into units amenable for subsequent coding. This chunking of the transcript required a researcher to evaluate the transcript and then to group a cluster of dialog together that appeared to be unitary and consistent. The goal of chunking was to create coherent blocks of dialog that were specific enough in they did not fall under multiple rating categories. Initial chunking was done on the basis of the Type category of the coding scheme (see next section, Verbal Coding Categories). Verbal chunks were further divided to ensure unique codes for all categories. Finally, the researcher who led the verbal analysis effort for Experiment 2, assigned codes for all categories included in the verbal coding scheme for Experiment 3.

Verbal Coding Categories. Verbal behaviors from Experiment 3 were analyzed using a revised version of the verbal coding scheme developed and used for Experiment 2 (Lickteig, et al., 2002). A brief description of the verbal coding scheme used for Experiment 3 is provided in this section. Appendix B provides more detailed documentation on the verbal coding scheme used for Experiment 3.

Verbal communications were analyzed for the categories of Source, Function, Type, and Factor used for Experiment 2. The categories of Valence and Command Considerations were also developed and used for Experiment 3, as noted. The coding schemes for Source, Function, Type, and Factor were as follows:

- *Source* coded the verbal behavior for who was speaking to whom.
- *Function* coded the verbal behavior for C^2 Functions: See, Plan, Move, Strike, Battle Damage Assessment (BDA).
- *Type* coded the purpose of verbal behavior: Share, Action, Direction, Ask, Process, Decide.
- *Factor* coded the verbal behavior for relation to Mission, Enemy, Terrain, Troops, Time, and Civilians (METT-TC) Factors. As for Experiment 2, each METT-TC Factor was subdivided into more specific sub-factors (e.g., Enemy Location, Identification and Disposition) for a total of 25 sub-factor categories (see Appendix B for more detail).

Notably, the System category was dropped from the Experiment 3 coding scheme. For Experiment 2, the System category was introduced to more precisely assess how FCS related assets (e.g., Roboscout, Micro-Unmanned Aerial Vehicle (UAV), Shadow UAV) were utilized or discussed by the command group players. System coded the specific Unit Cell asset that was the primary focus of each verbalization chunk. The System category was not used for Experiment 3, however, as it provided insufficient additional information.

Valence. A perceived shortcoming in the Experiment 2 verbal scheme was a failure to account for the evaluative information conveyed by the verbal communications of the participants. What communications conveyed positive versus negative information? Particularly, what did the communications convey on the status of accomplishing C^2 functions and tasks? Evaluative meaning is conveyed, or sought, in nearly all types of communication. For command and control communications, the evaluative information shared in communication should directly support the command group's decision making process.

For example, the statements "I can't get it to move" and "He is moving on plan at 30 miles per hour" would receive identical codes based on the Experiment 2 verbal coding scheme without Valence consideration. While these statements are "about" the same Move function, they convey very different information on the accomplishment of that function. Thus, Valence was introduced to distinguish communications conveying positive versus negative status on accomplishing basic C^2 functions and tasks.

For Experiment 3, each verbal chunk was scored as negative (–1), neutral/ inconclusive (0), or positive (1) with respect to its coded function. For example, "I can't get it to move" was assigned a negative value (–1); "Is it moving?"(without a verbal response to the question) was assigned a neutral value (0); and "He is moving on plan at 30 miles per hour" was assigned a positive value (1). The valence codes do not address the tactical goodness or appropriateness of the subject function or task, only whether it was being performed as anticipated, or not being performed as anticipated. Valence codes for the BDA function, however, require further explanation. BDA verbalizations were scored as negative (–1), if (a) no BDA images were available or useful, or (b) images were available, but the images indicated that the enemy asset still posed a threat. Table 1 provides examples of the Valence codes assigned to verbal chunks from Run 10 for each C^2 function.

Table 1

Examples of verbal chunks from Run 10 by Function with assigned Valence values of positive (1), neutral/inconclusive (0), and negative (-1)

Valence Function	Examples of Verbal Chunks
Plan	
1	I was just thinking about the birds being too far up there, up North Bring them South then. I will, I don't control anything, I've got to ask team to bring them further South. And I can do that, sir, if you don't mind. No go right ahead, keep them South, that's fine with me.
0	I got an idea, do you want to try something new? No.
-1	We have unconfirmed as of yet BDA on a tank in the South and a couple of tanks in center sector but we don't have enough intelligence yet to give us a good read of the battlefield other than the fact that he tried to move forward in the center, and I will keep you informed.
See	
1	There's an unknown radio hit.
0	They haven't fired any artillery yet, have they? (no response)
-1	Dang, there's nothing in my images here.
Move	
1	So we need to get those 2 micros back down there. They're coming down.
0	Where is the Synthetic Aperture Radar (SAR) bird? (no response)
-1	That one's stuck there, number 2 is just not… micro-UAV 2 is not responding.
Strike	
1	Did you? Did you fire 4? Yeah, I just fired 4.
0	Well, the question is, do we reengage? (no response)
-1	OK. Interestingly, you lost comms on the Precision Attack Missile (PAMs) that you sent. You see.

Table Continues

	that? PAM 54 lost comms. It didn't attack. Hold on a second, the last 2 PAMs that you sent lost comms and did not go to the target. You want me to show you? The one on the Darya did that too. Neither one hit anything. They both lost comms.
BDA	
1	Here is a better image. It looks like it might be perhaps a fire power kill, maybe a fire power, mobility kill.
0	PAM 16, where did that hit? (no response)
-1	Is it broke? Did we kill it?' I don't know, it doesn't look like it's broke from this image right here, it's hard to tell.
Other	
1	What's the red dot mean? It means that's where it detected something and takes a picture, or that's the place where the Garm was templated.
0	Blue 6, Black 6 (no response).
-1	I've got a right screen frozen.

Command Considerations. The second method refinement to verbal analysis for Experiment 3 was the addition of a coding category called Command Considerations. Another perceived shortcoming in the verbal analyses for Experiment 1 and 2 was the need for a more explicit relation between thought and action, particularly action in the form of verbal interaction. How do the verbal behaviors of the participants relate to the cognitive processes required for battle command? Notably, Army research on battle command has begun to identify a basic set of cognitive themes or mental scripts that commanders use to organize and visualize the battlefield (Lussier, Shadrick, & Prevou, 2003).

For Experiment 3, an exploratory set of Command Considerations was developed to relate participant communications with key cognitive patterns important to battle command. The nine (9) topics used to assess Command Considerations are listed in Table 2. Coding of the verbal data for Command Considerations did not treat the topics as exclusive. That is, the same verbal chunk could be could be coded under multiple topics or considerations.

Table 2

Command Considerations for Analyzing Command Group Verbalizations

Consideration	Description of Consideration
Plan	Execution is self-initiated and preceded by plan coordination/refinement.
Inform	Make information requirements known.
See	Battlefield visualizations that are dynamic/predictive/proactive.
Coordinate	Create synergistic effects with multiple assets/teamwork.
Assets	Use all assets available.
Situation Awareness	Continual situation assessment, dynamic/contingency planning.
Terrain/Time	Consider effects of terrain/time.
Enemy	Model a thinking enemy.
Mission	Keep sight of the big picture and mission intent.

Planning. At ARI's request, the planning phase for each run during Experiment 3 was recorded, in addition to the execution phase. Verbal interactions during planning were analyzed for Runs 10 and 11, in the manner previously described for the execution phase. Fidelity of the verbal recordings was lower than during execution, however, due to participants neglecting to use their headsets continuously during planning and preparation. Notably, it was observed that some planning discussions took place outside, as well as within, the C^2 vehicle. So not all verbal interactions related to planning were recorded or analyzed. Nevertheless, results on planning are provided in the results section.

Human-Computer Interactions

Methods for analyzing human-computer interactions (HCI), command group-C^2 prototype interactions, were reviewing, coding and quantifying data from video recordings of planning and execution phases from Run 10 (Too High Complexity). A quality versus quantity analytic strategy focused on a relatively comprehensive analysis of HCI performance during a *single* run versus a coarser analysis of multiple runs. Separate video recordings were captured at each of the two screens at each of the four command group player workstations (eight recordings total). These video recordings were reviewed and HCI records of the behavioral tasks performed were developed. A Head Up Display (HUD) flat panel was mounted to the ceiling in the forward area of the C^2 Vehicle, which allowed the Commander and Battle Managers to view a common screen. The players could toggle any of their eight screens or the driver/gunner's display to the HUD at any time. However, no video record was made of the information presented on the HUD.

The HCI Rating Scheme Development. Based on ARI's understanding of the new features developed in the C^2 prototype for Experiment 3, and a review of all Run 10 video recordings, the HCI rating scheme developed for Experiment 2 was revised and expanded (see Figure 1). As illustrated in Figure 1, the evaluation framework for HCI remained structured to basic C^2 Functions (Plan, See, Move, Strike) and Sub-Functions. However, the number of HCI tasks identified increased from 53 to 83 to reflect the new features added to the C^2 prototype for Experiment 3, and ARI's focus on documenting the HCI tasks performed during planning as well as execution.

An excerpt of the HCI rating scheme is provided in Table 3 for method clarification. A three-digit code based on the HCI rating scheme was applied to each interaction. The first digit designates the C^2 Function (Plan, See, Move, Strike). The second digit designates the C^2 Sub-Function (17 total). The third digit designates the 83 supporting HCI tasks. For example, the three digit code "113" designates: the Plan C^2 Function, the Create Mission/Course of Action (COA) C^2 Sub-Function and the Rehearse Plan task or interaction.

Table 3

Excerpt of HCI Rating Scheme

100 PLAN (Describe Tactical Situation, Concerns, and Future Activities, Request Information)

- 110. Create/Update a Mission and COA
  - 111. Create Overlay Graphics and Map Annotations
  - 112. Place platforms on the map (friendly and threat template)
  - 113. Rehearse Plan
  - 114. Execute Plan
  - 115. Point on Map Using Cursor/Indicate an Area
  - 116. Move Icons (vehicle or GCM) on Map Using Drag/Drop
  - 117. Modify overlay graphics
- 120. Alerts
  - 121. Create Alerts

This HCI taxonomy or evaluation framework facilitates comparisons across FCS C^2 experiments, and should support FCS task identification in future efforts. Iterative revision of the taxonomy and rating categories occurred during the analysis of video recordings. Two ARI-Knox researchers rated each of the video recordings from Experiment 3 Run 10 execution and planning phases. An example of HCI scoring and annotations for the Battlespace Manager's right screen during Run 10 execution is provided in Table 4 to clarify the analytic approach.

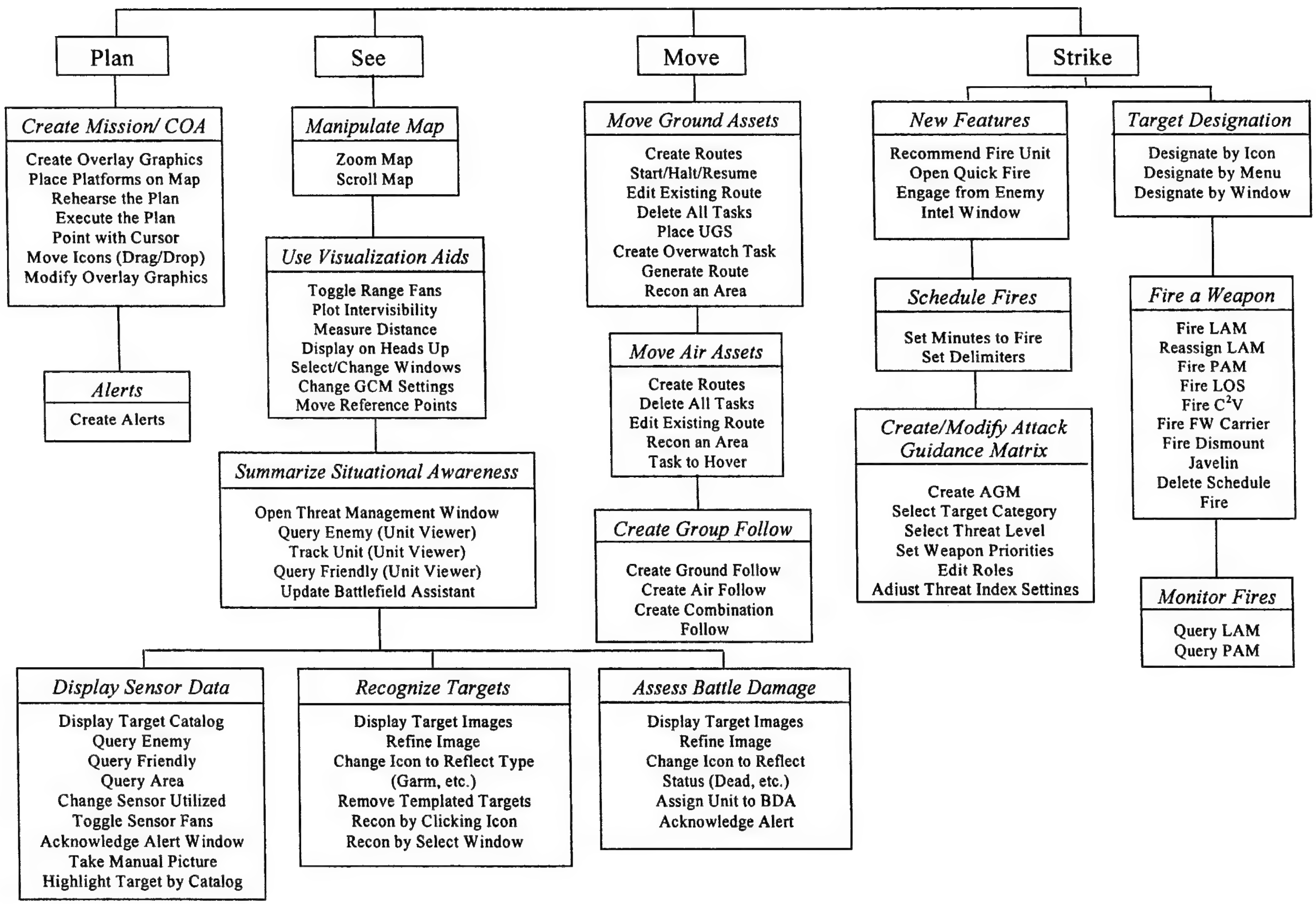

Figure 1. Human-Computer Interactions Rating Scheme.

The HCI task performance criteria included task frequency, duration, and errors. Transcripts described each HCI task performed, recorded Start and Stop times where appropriate, and annotated any performance errors observed. For HCI tasks that routinely required 5 seconds or less to perform, such as using Zoom and Scroll map tools, times were not recorded. However special attention was paid to record Start and Stop times for any instances where tasks took longer than 5 seconds to perform. The HCI task records and ratings were compared to generate an estimate of inter-rater reliability. The independent ratings yielded an index of agreement between raters of 96%. Results from the analysis are documented in the Results section.

Table 4

Example of Task Scoring Using HCI Rating Scheme

Start Time	Stop Time	Code	Description
0 00 00			Map 80%, Execution window 20%
0 00 38		325	Expand Execution window to 50% screen
0 01 04		344	Open State View window, deselect templated targets
0 01 14	0 01 41	325	Expand map to 100%, takes a long time to change
0 04 14		332	Target Query Automatic Target Detection(ATD)/Track (TK) A-22
0 04 22		332	Target Query ATD/TK A-22
0 04 31	0 04 40	332	Target Query ATD/TK A-22
0 05 10		311	Zoom Map Out
0 08 54		333	Fire Query Internetted Unattended Ground Service (IUGS) 1
0 08 59		333	Fire Query IUGS 3
0 09 10		351	Enemy Intel, delete, confirm
0 09 20		343	Select vehicle from menu, ATD1, remove from map
0 11 44		332	Chaser Query, PAM 16, mode = detonated
0 11 51		334	Target/Chaser Query, unknown 7
0 11 54		332	Chaser Query, Chaser 13
0 11 58		442	PAM Query, PAM 21 Mode attacking
0 24 51	0 25 12	351	Select target from menu, Chaser 6, Remove From Map

* Information Manager's Right Screen, Run 10 Execution Phase

HCI Data Reduction. For Experiment 3, high-resolution video recordings of each of the eight command group screens for Run 10 planning and execution were transferred to computer hard drive media for review by ARI-Fort Knox researchers. The Run 10 Execution phase was 83 minutes in length, so that the eight video recordings represented a total of approximately 12 hours of video data. The Run 10 Planning phase lasted 56 minutes, with the eight video recordings providing approximately eight hours of data. The review of each hour of screen video recording required approximately six hours of researcher time to create the HCI task record (annotated with task times) and to rate the transcript using the HCI rating scheme. After rating scheme refinement and expansion to accommodate new C^2 prototype features and tasks from Experiment 3, approximately 16 days of researcher time was required to create all HCI task

records for Run 10. Records for the eight command group screens ranged in length from 39 to 268 tasks for the Execution phase of Run 10, and from 1 to 164 tasks for the Planning phase.

Automated Measures Development and Validation

Automated performance measures are required to support training, evaluation and C^2 system design (Unit of Action Maneuver Battle Laboratory, 2002). This requirement applies to the FCS C^2 prototype, and to all future C^2 systems. Manual video data reduction of command and control performance can only examine a fraction of the data potentially available from each FCS C^2 experiment, or any future FCS training, testing and evaluation effort. For Experiment 3 the human-computer interaction (HCI) data for only one (Run 10) of the eleven runs was examined. Manual data reduction required approximately sixteen (16) days, as previously noted, to identify and tabulate the 1,043 human-computer interactions that occurred during Run 10 execution, and the 499 human-computer interactions that occurred during Run 10 planning.

In contrast, automated logs of human-computer interactions provide efficient and effective measures of command and control performance. The efficiency of automated measures equates to quick and inexpensive. It includes the ability to adjust the range and selection of data to include the performance of any or all C^2 users at any or all times during an operational exercise. The effectiveness of automated measures equates to increased scope and precision in the collection of C^2 performance data. It includes more meaningful measures by automatically correlating C^2 performance with the battlefield situation in which it occurred.

For Experiment 3, ARI requested a select set of key automated measures be developed to support human performance assessment for human-computer interaction, particularly command group and higher interactions with their C^2 prototypes. Table 5 lists and describes the automated measures requested. Members of the Technical Team created software that automatically logged *3 of the 23* automated measures requested, as indicated in Table 5. A supporting contractor team captured the logs for these three measures from the C^2 prototypes of each player and higher headquarters (Blue Team) workstation, at the end of each run execution phase. Notably, human-computer interactions during planning were not captured. The same contractor team then reduced the logged data in support of their own documentation requirements, and provided ARI a set of parsed metric files that could be viewed and modified in commercially available spreadsheet applications.

The focus of ARI's effort was to help the FCS C^2 program develop, refine and validate a relatively comprehensive set of automated measures to support training, evaluation and C^2 system design. For Experiment 3, this effort was limited to the 3 automated measures actually developed by the Technical Team. The method approach for validation of these 3 measures was to compare the log data obtained with corresponding manual measures from ARI's HCI analysis. Although data logs of automated measures were obtained for all 11 runs of Experiment 3, comparison was limited Run 10 as that was the only run manually reduced for HCI analysis.

The logged data provided to ARI consisted of 5 possible files per command group player, totaling as many as 20 parsed files per record run. The total number of files was dependent on whether or not the player performed the necessary tasks/keystrokes to activate a log tabulation of

the event by the software capturing the automated measures. The logged data provided to ARI also included data from higher headquarters (Blue Team), but comparison with manual data was not possible as video recordings of Blue Team workstation were not made. The five log files for each command group player were as follows:

- The alerts acknowledged during the record run.
- Images requested.
- Image requester tag (how the image was requested from the system).
- Image not available tag.
- Create route tag for ground and air units.

Results on ARI's effort to help the FCS C^2 program develop and validate automated measures are provided in the Results section.

Table 5

ARI's Requested Automated Measures List for Experiment 3

Measurement Category Automated Measure
See
Number of pictures/images available.
Number of pictures/images with actual enemy image of those available.
* Number of pictures/images opened.
Amount of time manipulating pictures (zoom, contrast, pan) to improve image.
Number of times *same* picture opened by *same* individual.
Number of times *same* picture opened by *different* individuals.
Alerts
Number and type of alerts set by duty position.
Number and type of alerts triggered/activated by duty position.
Time to respond to alerts by turning it off.
Number of times robotic vehicles auto halt (red line under the vehicle).
Time to respond to auto halt to re-tasking the entity.
Number of fratricide warnings (identify shooter/target pair).
Move Assets
* Number of times and task duration for Create a Route (ground platform).
* Number of times and task duration for Create a Route (air platform).
Strike
Number of times weapon fired and task duration (Network Fire [Netfire], Line of Sight [LOS], Infantry Fighting Vehicle [IFV]).
Number of times "Reassign" menu option selected for Loitering Attack Missile/Munitions (LAM).
Number of times target Type changed by selecting "Apply" button in Recon Window.
Number of times Target Status modified by selecting "Suspected," "Targeted," "Dead," etc.
Number of times sensors tasked to recon targets by selecting "OK" from Recon Target menu.

Table Continues

Assess Icon and Map Information Number of times cursor moved over a platform to bring up information window. Number of times "Templated" targets toggled off in status toolbar. Number of times Zoom Map options selected (box and/or arrows menu option). Number of times scroll arrows used for map manipulation.

*Designates the three (3) automated measures developed for Experiment 3.

Subjective Measures

A battery of 10 different subjective measures were developed and administered by ARI during Experiment 3. Three of these questionnaires were used during earlier FCS C^2 experiments. The seven (7) additional questionnaires are new instruments designed to provide more precise information on: workload (2 questionnaires), the new C^2 prototype features introduced in Experiment 3 (2 questionnaires), higher-order teamwork and decision making skills (2 questionnaires) and finally, repeated self-assessments of players' technical and tactical proficiency (1 questionnaire). These measures are described below and documented in Appendix H.

In-Place After Action Review (AAR). Immediately after the completion of each run, a five to ten minute structured interview or "In-Place AAR" occurred. This interview was conducted with player personnel still at their designated workstations in the mock-up C^2 Vehicle. This setting allowed players to review and refer to their tactical displays as they provided a summary of their performance during the run. This setting also supported video and audio recording of all player comments and references to their tactical displays. At the completion of the run, an ARI researcher entered the C^2 Vehicle and read a scripted question to each player that asked for a brief recap of "what went right and what went wrong" during the run relative to their duty position. To collect input from the three Battle Staff Managers prior to the Unit Cell Commander, the pre-specified order for player interviews was: Battlespace Manager, Information Manager, Effects Manager, and finally the Commander. These recorded interviews were also used to cue analysts to watch for specific tasks and operational events during HCI analysis of the recorded runs.

Workload and Performance. Immediately after the In-Place AAR, players exited the C^2 Vehicle and completed a brief survey on Workload and Performance Success. Players rated their perceived workload across five dimensions: Mental, Physical, Temporal, Effort, and Frustration (1 = Low to 100 = High). The workload questions and dimensions were adapted from the relatively standard Task Load Index (TLX) developed by National Aeronautics and Space Administration (NASA)—Ames Research Center (1986). Performance success was rated on this same questionnaire (1 = Failure to 100 = Perfect).

C^2 Prototype Support of FCS C^2 Functions and METT-TC Factors. After the final run (11), the players provided estimates of the C^2 prototype's effectiveness for C^2 functions (Plan, Move, See, and Shoot) and METT-TC factors (Mission, Enemy, Troops, Terrain, Time, and Civilians). Players were asked to rate "How effective was the C^2 prototype in support of C2 functions and METT-TC factors?" using a five-point rating scale (1= Very Ineffective to 5 =

Very Effective), with an additional "Not Applicable" response option. The questionnaire included definitions for each function and factor, and provided space for comments.

Skill Proficiency. The increased complexity expected in FCS combat systems and future combat conditions will place a premium on technical and tactical proficiency. Given these concerns, a survey instrument was prepared and administered repeatedly to gather self-reports of technical and tactical skills for key individual and collective tasks. The same questionnaire was administered after training (Post-Train) and after Runs 3, 5, and 9 to obtain estimates of initial proficiency, and proficiency as a function of practice. A "Comments" section in the survey solicited additional feedback from participants on skill proficiency.

Players were asked to rate skill proficiency on a 9-point scale (1 = Extremely Low Proficiency to 9 = Extremely High Proficiency). Individual skills questions addressed technical proficiency in using the C^2 prototype, and tactical proficiency at their assigned duty position. Collective technical skill questions asked players to rate the team's proficiency in using the C^2 prototype to perform collective tasks, and to direct the actions of robotic assets. Collective tactical skill questions asked players to rate the team's proficiency in communicating (gathering/sharing information) and making key decisions.

Workload on New C^2 Prototype Features. Automation does not always reduce workload. To more precisely examine workload, a new questionnaire was developed on selected new C^2 prototype features added for Experiment 3. The questionnaire addressed eight new features, and asked participants to rate their workload related to each feature on a 5-point scale (1 = Increased Greatly to 5 = Decreased Greatly). The survey was administered after Run 2 to allow participants to gain some familiarity with the new features, and after Run 9 to identify whether perceived workload decreased with practice using the new features.

New C^2 Prototype Features Effectiveness. The "New CSE Features Effectiveness" questionnaire was developed to more precisely assess the value of the new C^2 prototype features inserted for Experiment 3. This questionnaire asked the participants to rate the effectiveness of 13 new prototype features on a 5-point scale (1 = Very Ineffective to 5 = Very Effective). The questionnaire was administered at the conclusion of Run 5 after the players gained some familiarity with the automated features, and again after Run 10 to determine if their views of the effectiveness of the new features changed.

C^2 Prototype Support of C^2. To complement ARI's assessment of human-computer interactions (HCI), a questionnaire was developed and administered to assess how effectively the Experiment 3 prototype supported a set of HCI tasks identified after Experiment 2. The set of 12 HCI tasks examined are identified in Figure 8. Players were asked to rate the effectiveness (1 = Very Ineffective to 5 = Very Effective) of the C^2 prototype in support of each task. The questionnaire was administered after Run 8.

C^2 Teamwork Skills. For more effective battle command, research must focus on team process measures that underlie good command group performance, and not just battle outcomes. An open-ended questionnaire was administered that asked the players to provide examples of effective and ineffective C^2 teamwork skills. The four teamwork skills addressed by and defined

in the questionnaire were: Communication, Coordination, Performance Monitoring and Feedback, and Shared Situational Awareness. Due to procedural disruptions, the Commander and Information Manager completed the questionnaire after Run 5, and the Battlespace and Effects Managers completed the questionnaire after Run 7.

C^2 Decision Making. A primary goal of the FCS C^2 system design is to provide the command group with the information necessary to make effective decisions. While decision making might be inferred based on the allocation of functions and assets by duty position, inference is still required. An open-ended questionnaire was administered that asked the players to describe "Important Decisions" they had made in the preceding run, and to identify C^2 prototype features that supported the decisions made. Due to procedural disruptions, the Commander and Information Manager completed the questionnaire after Run 5, and the Battlespace and Effects Managers completed the questionnaire after Run 7.

Human Systems Integration Questionnaire. The ARI's efforts to improve measurement methods included adaptation of an instrument used by the Army Research Laboratory (ARL) to assess Apache Helicopter 64D (AH-64D) Longbow Crew Stations (Durbin, 2002). The Longbow may be a key component in future FCS organizations. This Human Systems Integration Questionnaire addressed two basic areas: Task Workload and C^2 prototype usability. The Task Workload dimension was designed to complement ARI's Experiment 2 approach for assessing HCI. Players were asked to rate their workload on a set of HCI tasks based on a 10-point scale (1 = "Workload Insignificant" to 10 = "Task Abandoned"). Players were also asked to identify additional tasks and recommend improvements to reduce workload for each task.

The C^2 prototype usability portion of this same questionnaire was designed to provide the software designers more explicit feedback on desired improvements to the prototype. Players were asked to provide a more detailed assessment of the prototype's usefulness based on: task clarity, task difficulty, display characteristics, ease of accomplishing key selected tasks, and ease of understanding the information provided in the prototype's various display windows. A final section asked the players to assess current and desired prototype default settings (e.g., search radius for LAM/PAM, saving adjustments made to manipulated sensor images). The set of default settings identified in the questionnaire were based on perceived user problems during ARI's HCI analysis for Experiment 2. This questionnaire was administered at the completion of Run 5.

Training. A training questionnaire was administered at the completion of Run 1 to determine if the players felt that the formal and informal training the command group received was adequate for performing as a member of the Unit Cell. The questionnaire focused primarily on the adequacy of the training content and the adequacy of training time for both individual and collective performance.

Analysis

The analysis and results provided here are limited to descriptive statistics. Inferential statistics were considered inappropriate due to limitations in experimental design and execution, and the small (n = 4) sample of subject players. Particularly, the manipulation of Complexity level across runs was confounded with run order effects. In addition, player personnel in

Experiment 3 varied across runs. Alternate personnel, including a Major and an Reserve Officers' Training Corps (ROTC) cadet, were required for the majority of runs as substitutes for at least some of the four primary Active duty Lieutenant Colonels. Alternate personnel had substantial training on C^2 prototype, and had performed at least pilot exercise runs.

Descriptive statistics were also warranted given the exploratory and iterative nature of the FCS C^2 program. The capabilities of the C^2 prototype and its integration with supporting simulation were incomplete and unreliable. Partial and system-wide software crashes disrupted the execution of experimental runs and on occasion resulted in less than graceful degradation of the supporting command and control environment.

Results

Results are organized in the following manner: Verbal Interactions during execution and then planning, HCI during execution and then planning, and Subjective Measures.

Results on verbal and HCI interactions will focus primarily on the execution phase. Results from the planning phase are provided after the execution phase. A rationale for this somewhat reverse order of presentation seems in order. First, prior FCS C^2 experiments and reports focused almost exclusively on the execution phase versus planning. For program consistency and priority of ARI's analytic effort, therefore, a primary focus on execution was maintained. Second, the data collected and results reported on planning are regarded as incomplete and preliminary findings.

The fidelity of the verbal recordings during planning was not high. Some planning communications were not collected due to inconsistent use of headsets in the C^2 vehicle, and discussions outside the C^2 vehicle. Moreover, planning activities were often limited, as the players had performed very related planning on prior runs. In particular, planning with respect to Terrain was curtailed. Prior experience with the National Training Center (NTC) terrain database included not only the participants 30+ experimental runs during Experiments 1-3, but also numerous live rotations at the NTC during their Army careers. Players routinely re-used many of the same graphic control measures (e.g., phase lines, axes of attacks, and named areas of interest) during planning that they had created and stored in their C^2 prototypes for earlier runs.

Verbal Interactions—Execution Phase

Run Characteristics. A brief review of key run characteristics is provided. Verbal communications were transcribed, coded and analyzed to identify categories and patterns of communication, as described in the Method section. Table 6 characterizes Runs 10 and 11 according to duration, cumulative amount of silence, and number of verbal chunks. Both runs lasted approximately 1.5 hours. During the runs, verbal interactions were almost continuous. Cumulative time in silence, counting silences lasting 3 seconds or more, was under 3.5 minutes or less than 4% of total run time.

Table 6

Key Characteristics for Execution Phases, Runs 10 and 11

Complexity	Too High	High
Run Number	10	11
Run Duration	84 minutes	89 minutes
Cumulative Silence*	3.4 minutes	2.9 minutes
# Verbal Chunks	436	461

*Timing initiated after 3 seconds of silence.

Communication by Source. Figure 2 displays the percentage of verbal communication by Source. Source data identifies the participants engaged in communication for each verbal chunk. As expected based on prior experiments, the vast majority of communications were internal to the command group players (Within Cell--Black). Remaining verbalizations were fairly evenly divided among chunks in which the command group spoke with superiors (Black/Blue), subordinates (Black/Subordinates), and support personnel and observers in the C^2 vehicle (Other). These Source results help clarify that the command group's almost continuous stream of communication was predominantly with one another. Notably, this pattern of steady verbalization occurred in the context of (a) the command group's access to a visually rich and timely depiction of the battlefield on their C^2 prototype, and (b) ongoing interactions with their C^2 prototypes to command and control a predominantly robotic force, as reported later in the HCI Analysis section.

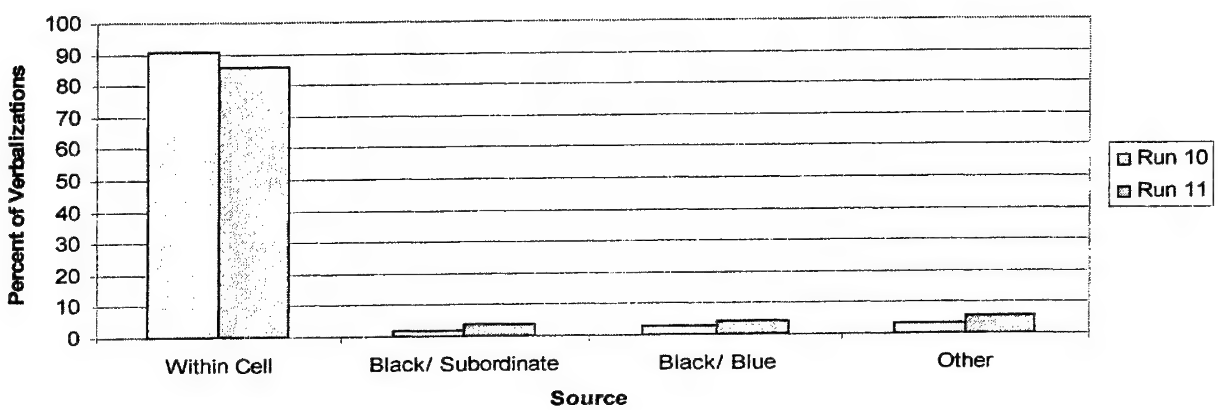

Figure 2. Percent of Verbalization by Source, Runs 10 and 11 Execution.

Communication by Function. Figure 3 depicts the percent of verbal communication by Function during execution, for Runs 10 and 11. Communications related to the See function were the most frequent, about 30% of all verbalizations. The next most frequent C^2 functions discussed were Strike and Move, followed by BDA. Comparing across runs, the relative percentage of communications by C^2 function was remarkably similar. Moreover, the relative percentage of communications by C^2 function was similar to that observed in Experiment 2.

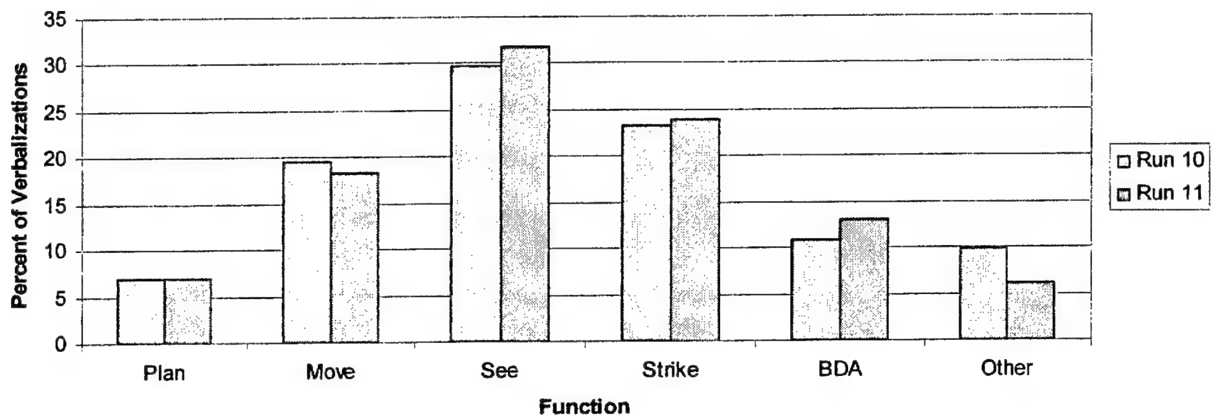

Figure 3. Percent of Verbalization by Function, Runs 10 and 11 Execution.

Communication by Valence. Valence ratings were assigned to verbal behaviors in order to distinguish communications conveying positive versus negative status on accomplishing basic C^2 functions and tasks within those functions, as described in the Method section. Results on Valence by Function are summarized in Figure 4 (Run 10) and Figure 5 (Run 11). Overall, by far the majority of verbal communications were rated positively in terms of Valence. This pattern of predominantly positive status on accomplishing C^2 Functions was found for See, Plan, Move, and Strike related communications. In contrast, BDA and Other related communications were relatively more negative. For BDA, percentage of positive versus negative verbalizations was nearly equivalent. For "Other" communications, particularly technical status comments, communications were predominantly negative. While the Other communications do not directly relate to C^2 Functions, they provide useful information on player perceived technical limitations in the C^2 prototype (e.g., slow processing and system crashes) that may have undermined the command group's performance across functions.

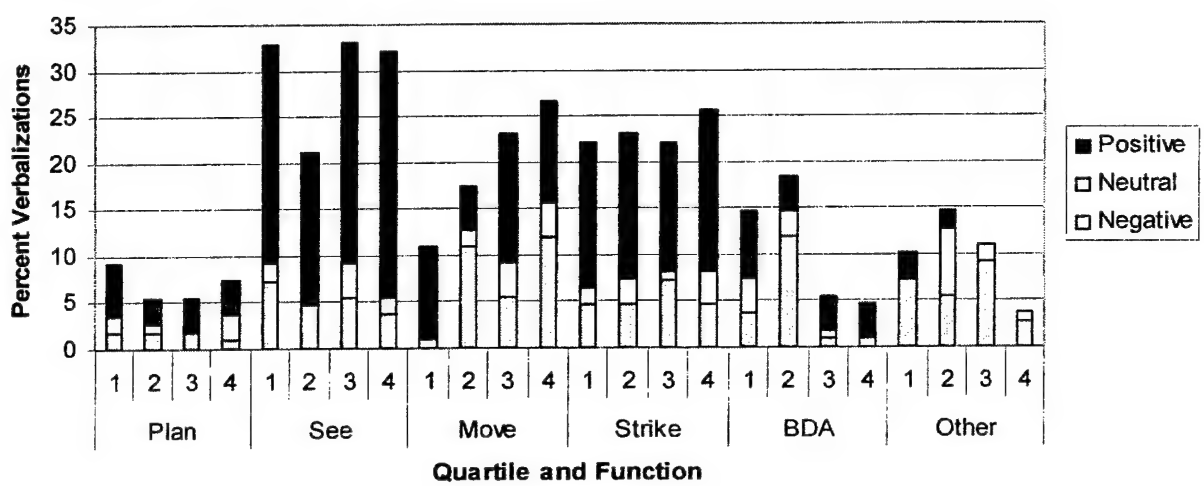

Figure 4. Percent of Verbalization by Function, Valence and Quartile, Run 10 Execution.

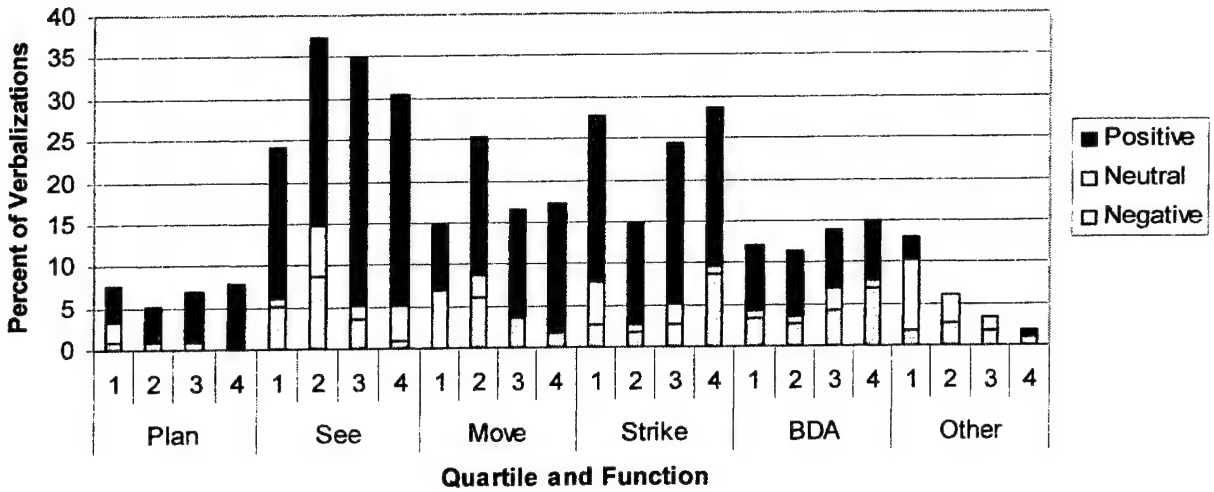

Figure 5. Percent of Verbalization by Function, Valence and Quartile, Run 11 Execution.

Negatively valenced communications provide useful diagnostic information on the capabilities of the C^2 prototype. Efforts by the FCS C^2 program's Technical Team to refine the C^2 prototype should attend closely to the problems discussed in negatively rated verbalizations. For example, Figure 4's quartiles help pinpoint when negative verbalizations occurred in Run 10. During quartile 2 of Run 10, player verbalizations indicated problems with Move and BDA functions. These communications stress the difficulty of controlling the micro-UAVS that resulted in the loss of two of the four allotted the Unit Cell. For BDA, negatively valenced communications indicated the participants' inability to kill designated targets. During Quartile 4 of Run 10, negative Move related comments stressed the inability to maneuver several platforms, including Future Warriors, Robo-Scout ground surveillance radar (GSR), and LOS. In fact, Run 10 was terminated about the time all systems became "frozen." Notably, the 84-minute duration of Run 10 allowed the Unit Cell sufficient time to complete their mission.

Communications by Type. Type categorizations were designed to help identify the purpose of the command group's communications. Figure 6 depicts the percentage of verbal interactions by Type for Run 10 and 11. The distributions by Type are fairly similar across runs. The primary types of communications were Share and Ask that together accounted for over 70% of the verbalizations in each run. The relative dominance of Share and Ask communications appeared to underscore, respectively, the collaborative nature of the command group's work, and a fair degree of uncertainty about the unfolding battlefield situation. The pattern of distributions by Type is also similar to patterns observed in Experiment 2.

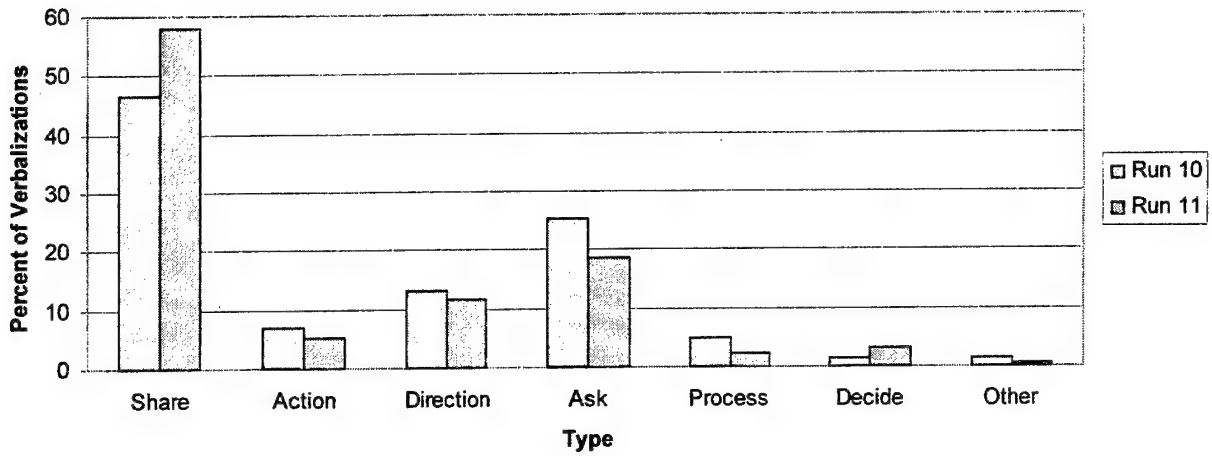

Figure 6. Percent of Verbalization by Type, Runs 10 and 11 Execution.

Communications by METT-TC Factors. Figure 7 shows the frequency of verbal interactions by METT-TC Factor (Mission, Enemy, Terrain, Troops, Time, Civilians) for Runs 10 and 11. Troops and Enemy related communications virtually monopolized verbal interaction, together accounting for over 90% of the chunks. Recall, METT-TC Factors were further analyzed into 25 sub-factors. For example, Enemy categories included 4 sub-factors (Location, Identification, Disposition, and BDA). Figure 8 shows the distribution of Enemy related communications by sub-factor. Almost 80% of Enemy related communications concerned Location or BDA, with approximately equal amounts of discussion devoted to each. This pattern may indicate the command group's collaborative and balanced efforts to "find and fix" Enemy elements.

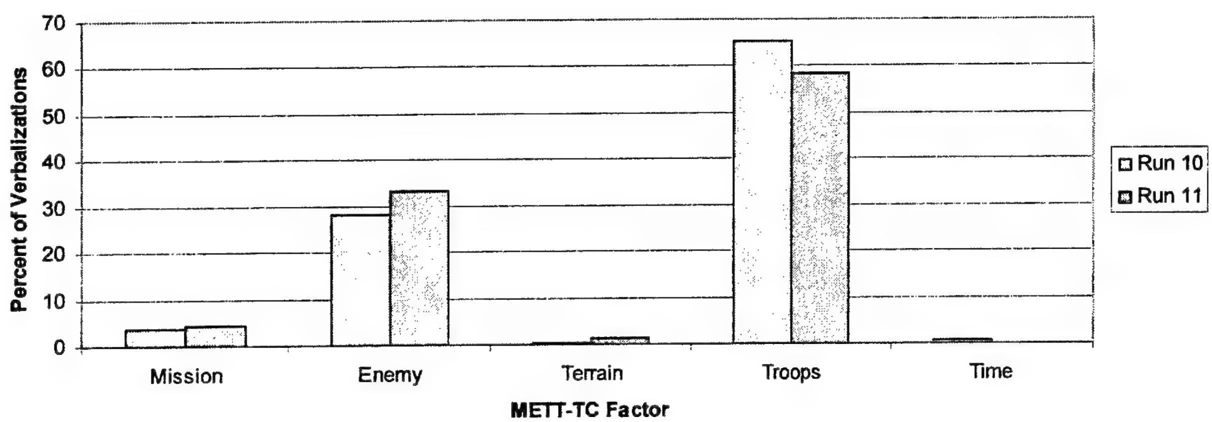

Figure 7. Percent of Verbalization by METT-TC Factor, Runs 10 and 11 Execution.
Note: Civilians = 0% in Runs 10 and 11; Other = 1.6% and 2.6%, Run 10 and 11 respectively.

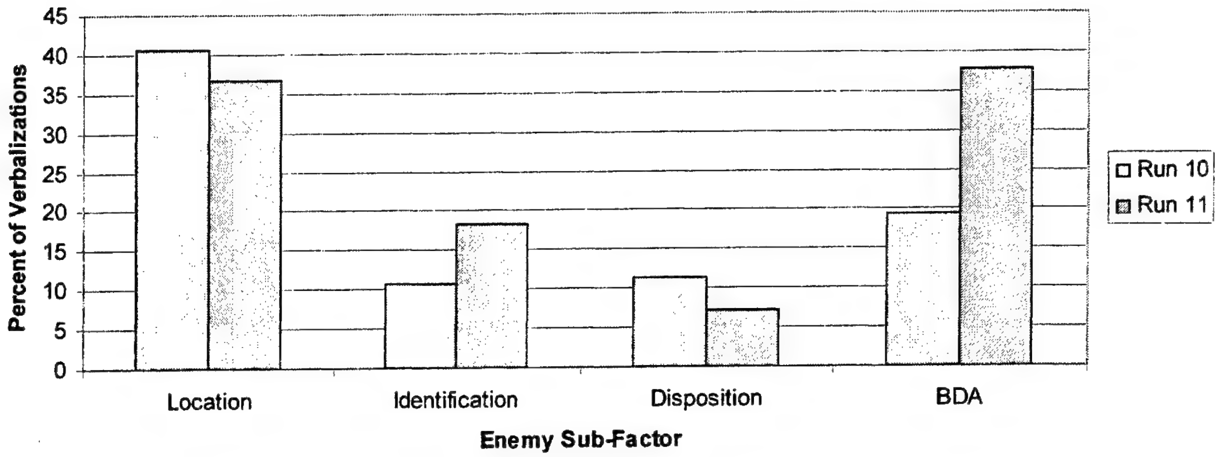

Figure 8. Percent of Verbalization by Enemy Sub-Factor, Runs 10 and 11 Execution.

Similarly, Troops related communications were categorized into 14 sub-factors, and their distribution is shown in Table 7 with selected sub-factors shown in Figure 9. As in Experiment 2, the most frequent Troops sub-factor was Strike-Lethal communications, related to launching, firing, and deploying with intent to destroy (e.g., LAMs). The next most frequent Troops sub-factor was Move with verbalizations related to moving, managing, and maneuvering Unit Cell assets. Finally, there was a notable decrease in complaints about the C^2 prototype Information Technology (IT)/Commander's Support Environment (CSE) in Experiment 3, compared to Experiment 2. This decrease seems to suggest the command group experienced fewer technical problems with their C^2 prototypes and/or a more stable operational environment during Experiment 3.

Table 7

Percent of Verbalization by Troops Sub-Factors, Runs 10 and 11 Execution

Troops Factor	Percentage (Run 10)	Percentage (Run 11)
Position	1.8	1.5
Mobility	1.0	1.1
Sensors	10.2	12.6
Strike Ability	3.2	4.1
Communications	5.6	0.3
IT/CSE	9.8	4.8
Caution	6.0	2.9
Survivability Move	2.5	1.5
Loss	2.5	1.8
Move	25.3	28.5
Strike-Lethal	30.6	34.4
Strike-Nonlethal	0.3	2.6
Training	0	0
Other	1.0	3.7

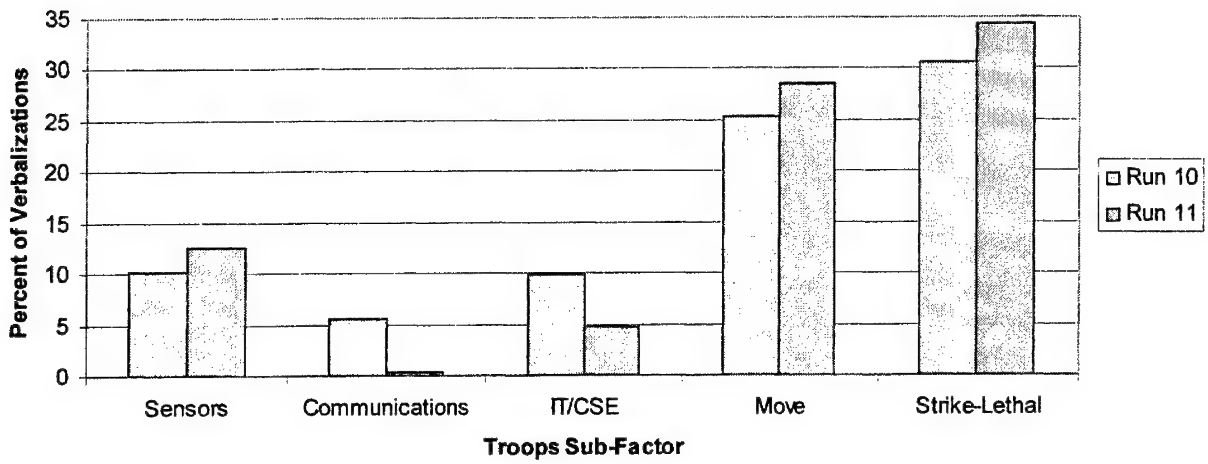

Figure 9. Percent of Verbalization by Selected Troops Sub-Factors, Runs 10 and 11 Execution.

Command Considerations. Figure 10 illustrates the frequency of communications for each of the nine categories of Command Considerations. These data are presented in terms of absolute frequency, rather than percentages, given the exploratory nature of this analysis. The ARI's initial concern was if, and how often, such considerations occurred. Table 8 provides examples of communication segments coded by Command Considerations. Communications related to all nine Command Considerations were found in each run. This finding was expected for the expert command group in Experiment 3, if the cognitive considerations identified are required for battle command. For comparisons with less experienced participants, such as Cadets, Command Considerations may prove more discriminating and useful. The Comprehensive Report by ARI across all four (4) FCS C^2 experiments will include a section on Cadet performance from the FCS C^2 Summer Study.

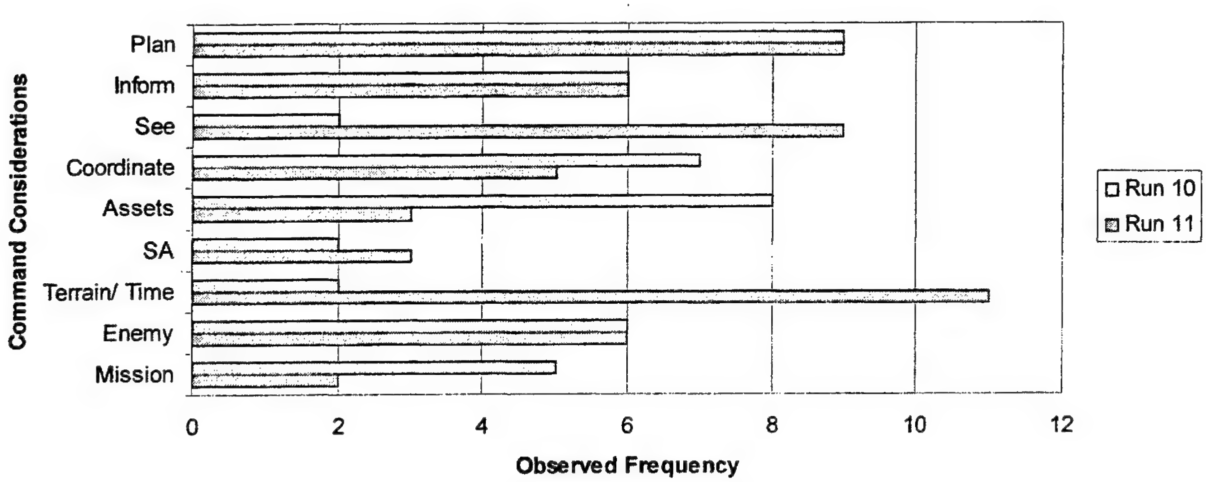

Figure 10. Frequency of Command Considerations, Runs 10 and 11 Execution.
Note: Command Considerations defined in Table 2.

Table 8

Examples of Verbal Communications by Command Considerations

Consideration	Example
Keep sight of the big picture and mission intent.	I think they are probably dead, or mobility kills which for this scenario is both good.
	Yeah.
	We won't waste any more rounds on him.
	Yeah. Actually, just as long as we hit him even if they are fire power kills, I don't care less.
	Jack, what we don't want to do is get into the Netfires.
	Yeah exactly, exactly.
	So that's why I'll leave the troop transport there, to protect our flank.
	Protect the flank.
Model a thinking enemy.	That means he is moving out of sector.
	I mean they dropped it right on top of him.
	Either that or he is trying to reposition from where they told us he was at Start Ex.
	That could very well be.
	Right in the middle of the valley, back to a ridgeline, or forward into the gap there.
Consider effects of terrain/time.	I'm just looking, I'm trying to find that freaking keyhole up in here.
Continual situational assessment and dynamic/contingency planning.	I stopped, go to the heads up. I stopped him, that's his eyes so if this guy continues in this direction that's a keyhole. And if he ends up here I ought to be able to see him and that would be within Javelin range.
	Okay.
	If he pops up in any of these areas here.
Use all assets available.	Brooks, I don't think we are going to get the A160 any time soon, so I need you "Sir" to get the GSR up on some higher ground there right in front of you and get a mast up.
Create synergistic effects with multiple assets/teamwork.	Hey Jack, head's up chief, here's my second IFV team in the South.
	Okay.
	It runs…
	Now that tank.
	Yeah we got to kill him. He dies first.
	But he runs here, this is pretty much covering the meadow this point right here is where he stops…infantry North.
	But this time, all hell is going to break loose.

Table Continues

	All of a sudden two different infantry teams are popping up on the ridge, well one on the ridge and one on the road, but they are only 300m apart. All of a sudden he's got clear visibility across the valley.
	Very nice, now which one, that's the IFV.
	That's the IFV with 2 mounted teams.
	Okay.
	Now I've got the dismounts starting off, 2 routes, this guy is here, he moves here, and all of a sudden…
	That's a pretty good view.
	He gets a good view out of the valley. This bobo down here. He is going to move down this route, and he should be able to, shortly, acquire anything out in that open area there, at this position. See where that is open?
	Oh yeah.
	So that's right now his route plan.
	For dismounts?
	Yeah.
Battlefield visualizations that are dynamic/ predictive/proactive.	Hey Dave, if I was a guessing man, I would say that radio link 3, which is up there where that PAM lost comms, has now become unknown 27. I'm just telling you, I think that very well may have moved that down there.
Make information requirements known.	I want to see in front of us with those Micro-UAVs, it takes a long time to try to develop what's in front of us, so we need to do that as quickly as possible.
Execution is self-initiated and preceded by plan refinement/coordination.	No other detections, Micro-UAVs going out there taking pictures.
	Go micro go.
	Got one back here. Micro 1 waiting for its detections up there in the North, to go and take pictures there. The other 3 are out on the route.

Verbal Interactions—Planning Phase

This section provides results of the verbal interactions by the command group during the planning phase. The introductory discussion of Planning Characteristics stresses the incomplete and preliminary nature of planning results.

Planning Characteristics. Verbal communications during planning were transcribed, coded and analyzed to identify categories and patterns of communication, as described in the Method section. Table 9 characterizes the two planning phases analyzed according to their duration, cumulative amount of silence, and number of verbal chunks. As indicated by duration times, planning phases were notably shorter than the execution phases. During the execution phase for each run, verbal communications occurred 96% of run time. In the planning phase, however, verbal communications occurred during 86% of Run 10 and 75% of Run 11. Possible

explanations for less verbal interaction during planning are that not all participants remained in the C^2 vehicle, and headsets were not continuously wore during the entire planning phase.

Table 9

Key Characteristics for Planning Phases, Runs 10 and 11

Run Number	10	11
Run Duration	56 minutes	39 minutes
Cumulative Silence*	7.6 minutes	10.1 minutes
# Verbal Chunks	75	61

*Timing initiated after 3 seconds of silence.

A more interesting and important explanation may be *actual* differences in the communication requirements for planning versus execution. For example, players appeared to spend more time entering duty-specific mission data (e.g., routes and tasks) into their C^2 prototypes during planning. However, method shortcomings should be eliminated or at least reduced before more firm conclusions on actual differences are reached. Moreover, given the smaller sample of verbal communications during planning, more variation in planning results should be expected and less confidence should be placed in apparent differences. In sum, ARI's emphasis on the exploratory nature of planning results is stressed.

Communication by Source. Figure 11 displays the percentage of verbal communications during planning, by Source. Source data identifies the participants engaged in communication for each verbal chunk. Similar to the execution phase, the majority of communications were internal to the command group players, Within Cell (Black). Remaining verbalizations were evenly divided among chunks in which the players spoke with superiors (Black/Blue), subordinates (Black/Subordinates) and support personnel and observers in the C^2 vehicle (Other).

Communication by Function. Figure 12 provides the percent of verbal communications by Function during planning for Runs 10 and 11. For both runs, Plan related communications were the most frequent category by function, almost 50% of all verbalizations. This high proportion of Plan related communications is hardly surprising, as the focus of these sessions was planning, but it indicates the potential for basic differences between planning and execution phases. The next most frequent planning communication category was "Other" for verbalizations not matching any of the pre-defined set of C^2 functions. Overall, the results suggests that most C^2 functions were addressed during planning, but more careful examination may require revision of the methods and codes used to assess planning verbalizations, particularly the Other category.

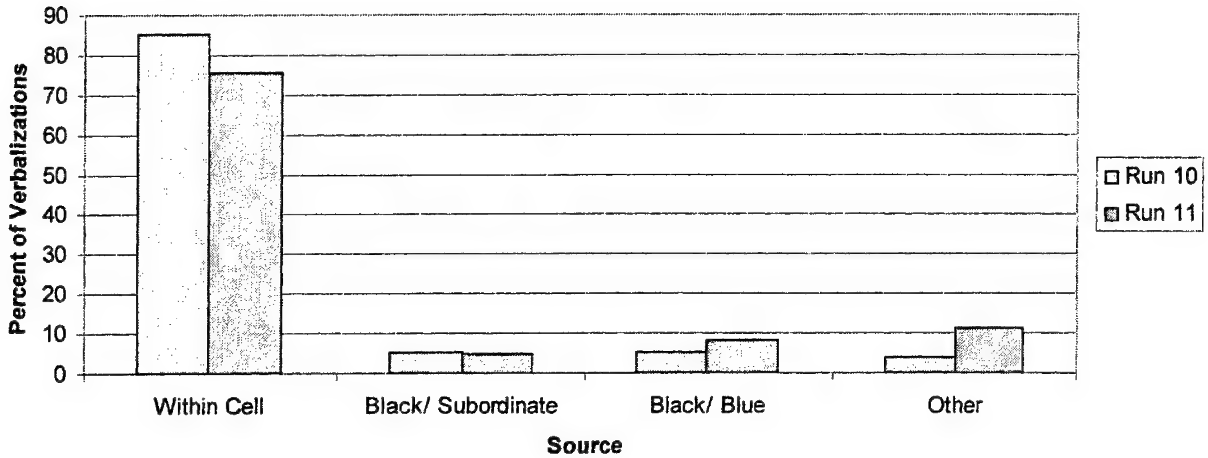

Figure 11. Percent of Verbalization by Source, Runs 10 and 11 Planning.

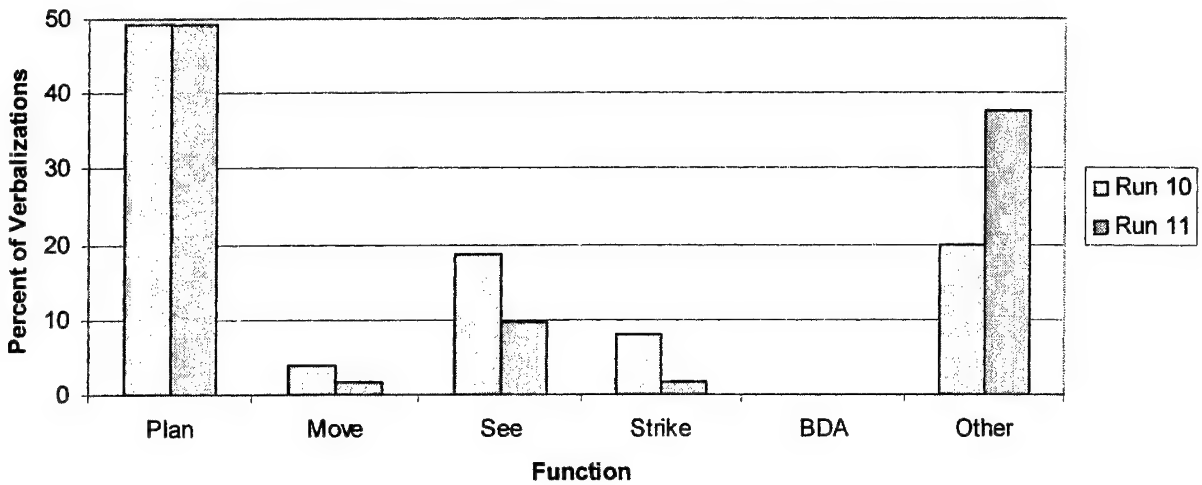

Figure 12. Percent of Verbalization by Function, Runs 10 and 11 Planning.

Communication by Valence. Recall, Valence codes were assigned to verbal behaviors in order to distinguish communications conveying positive versus negative status on accomplishing C^2 Functions and supporting tasks. Results on Valence by Function are summarized in Figure 13 for Runs 10 and 11. Overall, by far the majority of verbal communications were rated positively in terms of Valence. Most problems in accomplishing C^2 functions during planning were associated with Plan and See functions during Run 11.

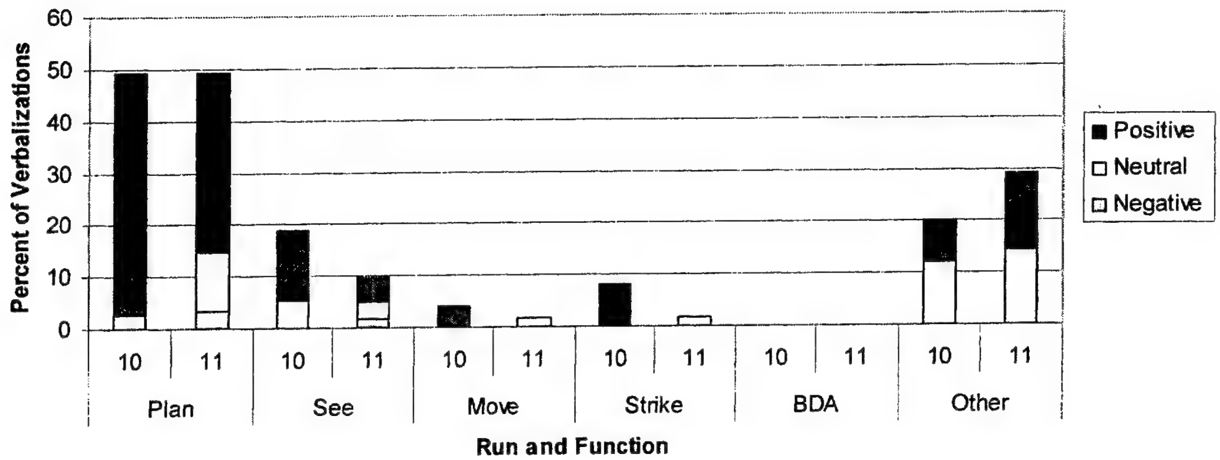

Figure 13. Percent of Verbalization by Function and Valence, Runs 10 and 11 Planning.

Communications by Type. Type categorizations were designed to help identify the purpose of the command group's communications. Figure 14 depicts the percentage of verbal interactions during planning by Type, for Runs 10 and 11. As with execution, the primary types of communications were Share and Ask that together accounted from 50% (Run 10) to 70% (Run 11) of all planning verbalizations. Again, the relative dominance of Share and Ask communications appears to underscore, respectively, the collaborative nature of the command group's work, and a fair degree of uncertainty about the upcoming battlefield situation.

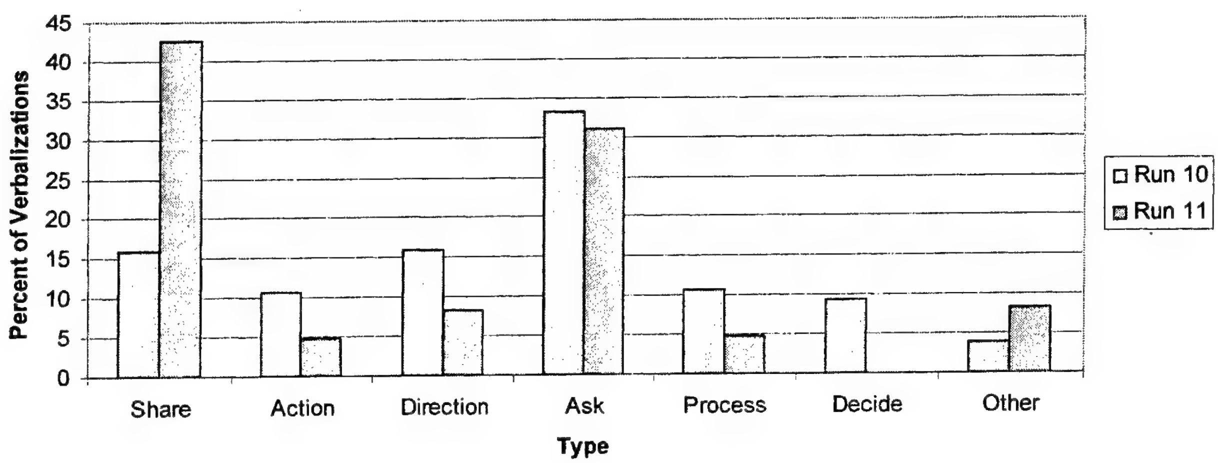

Figure 14. Percent of Verbalization by Type, Runs 10 and 11 Planning.

Communications by METT-TC Factors. Figure 15 shows the frequency of verbal interactions by METT-TC Factor for Runs 10 and 11. Across both runs, Troops related communications were the most frequently discussed topic during planning. However, during Run 10, communications related to Time (52%) were the single most discussed METT-TC Factor during planning. In addition, Enemy and Mission related communications also dominated planning conversations. For example, during Run 10, 25% of all planning communications were Mission related, indicating the players' concerns with mission goals and plans prior to execution.

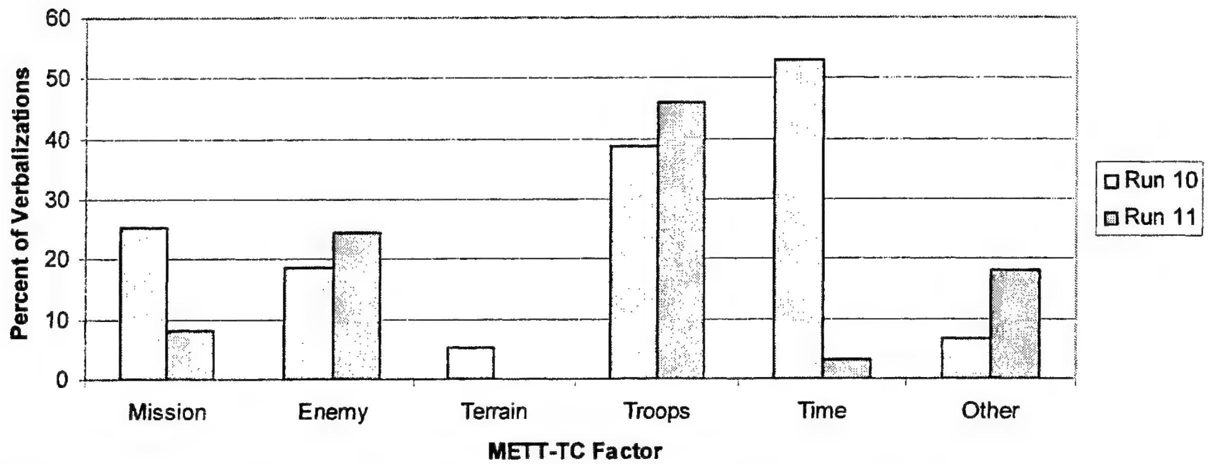

Figure 15. Percent of Verbalization by METT-TC, Runs 10 and 11 Planning.

Table 10 and Figure 16 provide a closer look at Troops related communications by sub-factors. Strike Ability and Strike-Lethal were dominant discussion topics and underscored the command group's concerns with launching, firing, and deploying lethal effects. Notably, a "hot" topic under Troops assets was the C^2 prototype (IT/CSE) that accounted for 31% of all Troops related communications during Run 10 planning, and 25% during Run 11 planning.

Table 10

Percent of Verbalization by Troops Sub-Factors, Run 10 and 11 Planning

Troops Factor	Percentage (Run 10)	Percentage (Run 11)
Position	0	7.1
Mobility	0	0
Sensors	0	0
Strike Ability	34.4	0
Communications	6.9	21.4
IT/CSE	31.0	25.0
Caution	0	0
Survivability Move	0	0
Loss	0	0
Move	24.1	17.8
Strike-Lethal	34.1	14.3
Strike-Nonlethal	3.4	3.6
Training	0	0
Other	6.9	10.7

Verbalizations about the C^2 prototype were predominantly centered on how to correctly input operational plans. In particular, players expressed uncertainty about what could be done with the C^2 prototype in planning versus execution phases. Given these were the last runs during Experiment 3, verbalizations about the C^2 prototype indicate that training, particularly in support

of planning, was inadequate. Understanding the complexities of the C^2 prototype, particularly planning inputs and parameters related to automated See, Move, and Strike functions, requires structured training directed at these functions with clear operational feedback.

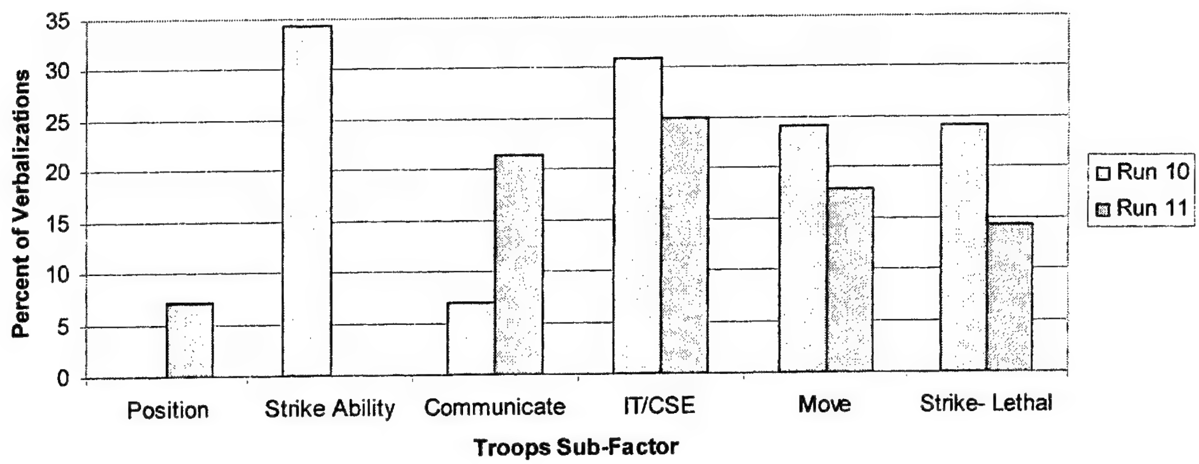

Figure 16. Percent of Verbalization by Selected Troops Sub-Factors, Runs 10 and 11 Planning.

Command Considerations. Figure 17 illustrates the frequency of communications for each of the nine categories of Command Considerations during planning for Runs 10 and 11. As with execution, these data are presented in terms of absolute frequency, rather than percentages, given the exploratory nature of this analysis. Communications related to nearly all Command Considerations occurred during the planning phases.

Two near exceptions included the relatively low frequencies tabulated for Coordinate (create synergistic effects) and Assets (use all assets available). However, with experienced command groups, the coordinated use of all assets may be more implied than explicit. Comparisons with less experienced participants are recommended. Such comparisons may identify interesting differences between experts, intermediates and novices and provide an empirical basis for training and evaluating Command Considerations.

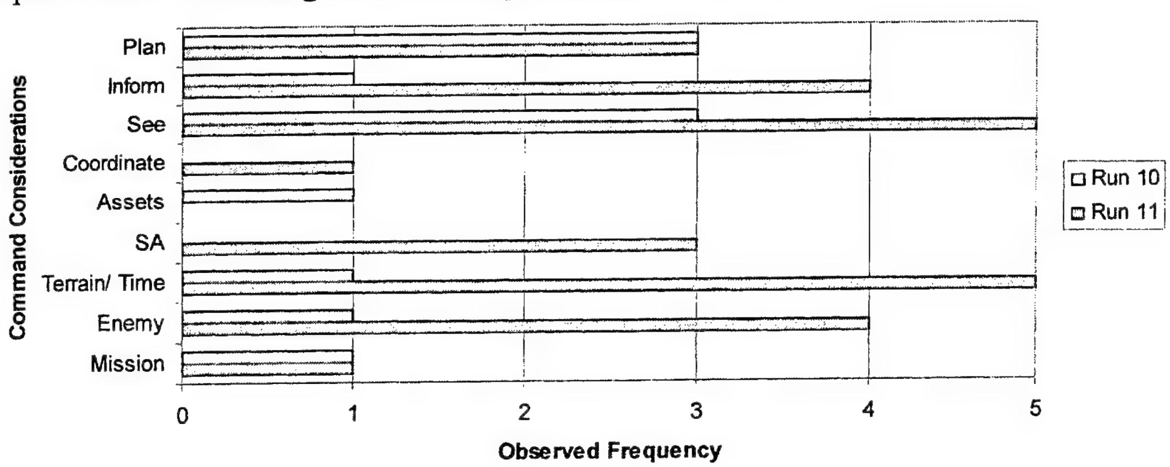

Figure 17. Frequency of Command Considerations, Planning Runs 10 and 11 Planning.
Note: Command Considerations defined in Table 2.

Human-Computer Interactions—Execution Phase

The primary measures of performance for assessing HCI were task frequency and duration by C^2 Function and Sub-Function. Overall, the results provide a detailed account of the human-computer interactions required to command and control the Unit Cell during Run 10 execution. Results indicated the frequency, duration and type of HCI tasks differed across the command group, and across left versus right screen performance at each duty position. Performance time and errors were less useful as performance criteria. Performance times for most interactions were typically 5 seconds or less, and did not appear to be associated with any other indicator of success or failure. However, such inferences are limited by the present focus on only one experimental run.

Time Duration for HCI. Time duration for task completion was examined as an important aspect of HCI performance. Tasks requiring longer performance times could be candidates for redesign, machine aiding, or additional training. Task performance time was estimated by identifying Start and Stop actions, typically involving the selection of a menu option. Overall, during the execution phase for Run 10 the command group players performed a total of 1,043 human-computer interactions. Approximately 13.5% of these interactions (141 of the 1,044) required more than 5 seconds to perform. Table 11 provides frequency data and performance times in seconds, mean and standard deviation (SD), for these long duration tasks. Notably, the same task types listed in Table 11 were sometimes more quickly performed, required less than 5 seconds. Accordingly, Table 11 reports only the subset of interactions for the tasks listed that took longer than 5 seconds to perform.

Table 11

HCI Long Duration* Tasks by Frequency and Time, Run 10 Execution

Human-Computer Interaction Task	Frequency				Time in Seconds (Mean/SD)
	Commander	Battlespace	Information	Effects	
Create Ground Route	---	11	---	---	17.6/9.4
Create Air Route	---	1	18	---	15.1/9.8
Recognize Targets	1	---	5	---	17.0/12.6
Assess Battle Damage	8	24	67	4	18.2/12.7
Crash/Reboot	---	2	---	---	51.5/27.6

*Long duration tasks requiring more than five (5) seconds to perform.

Success Criteria for HCI. Task performance "success" was not a useful performance criterion for Experiment 3. There was little discernable evidence that command group players made serious mistakes in performing HCIs, and no clear indication that errors impacted Unit Cell performance. The only tasks associated with clearly observable errors were eleven (11) inadvertent clicks on Graphic Control Measures (GCMs).

Frequency of HCI by Duty Position and Function. Figure 18 presents the frequency of interactions performed at each player's workstation by C^2 Function. Across player workstations, the greatest number of interactions performed supported the ability to See the battlefield. In order by amount, the percentage of See related interactions performed by each player was Commander (96.2%), Information Manager (89.9%), Effects Manager (64.6%), and Battlespace Manager (60.3%). Interactions supporting Strike also represented a large proportion of the total tasks performed, particularly for the Battlespace Manager (29.0%), and Effects Manager (35.4%). Much smaller proportions of Move related interactions occurred, primarily by the Battlespace Manager (9.0%), and Information Manager (8.0%). Only one Plan related interaction (performed by the Battlespace Manager) was identified, involving the use of the overhead display to show the location and sensor reach capability of the Roboscout vehicle. To clarify the presentation of results, this single instance of a Plan related interaction is not included in the figures, tables or discussion of HCI during the execution phase.

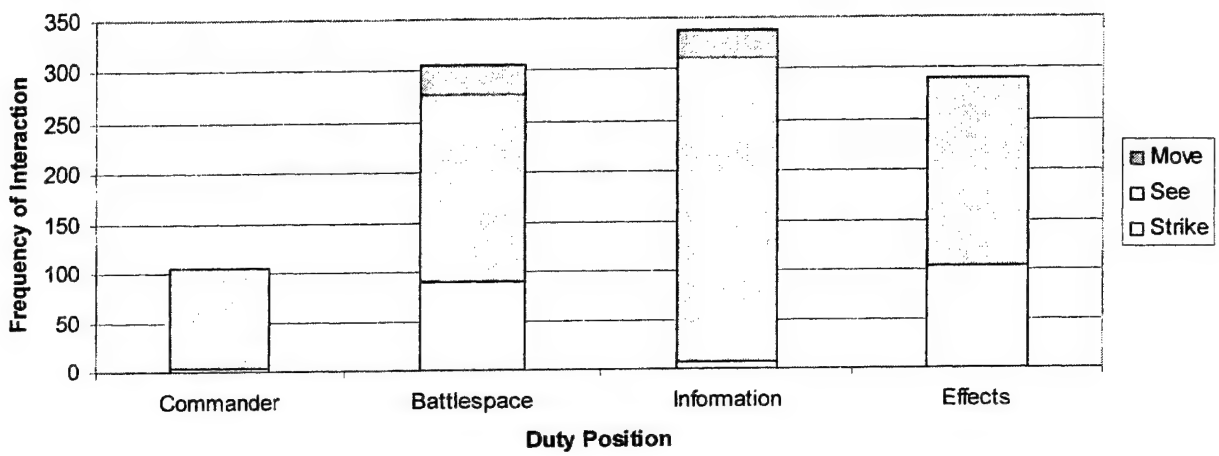

Figure 18. Frequency of HCI by Duty Position and C^2 Function, Run 10 Execution.

Frequency of HCI by Sub-Function and Duty Position. Table 12 provides frequency data by C^2 Function and the 12 Sub-Functions performed during Run 10 execution. Notably, no HCI tasks were performed on the remaining five of seventeen Sub-Functions depicted in Figure 1. Sub-Functions not performed were Create Mission/COA and Alerts under Plan, Create Group Follow under Move, and Schedule Fires and Create/Modify AGM under Strike. The complete set of HCI frequency data by duty position during Run 10 execution is provided in Appendix F.

Across all player workstations, the most frequent interactions were performed on See related tasks. The most frequent interactions by the Commander and Battlespace Manager were Display Sensor Data, respectively 45 and 66 interactions. Display Sensor Data interactions primarily involved moving the cursor over enemy and friendly icons to "pop" up a window that temporarily displayed information about that icon (e.g., type of target, time when detected, and type of sensor that detected target).

The most frequent interactions for the Information Manager were Assess Battle Damage (132 interactions). This interaction requires opening the Enemy Intelligence window and reviewing a sensor picture to determine the extent of damage to the pictured vehicle, and then

updating the target image information to reflect its type and status. Most frequent interactions performed by the Effects Manager involved Manipulate Map tasks, which included changing the magnification of the map, and scrolling the display to present different areas of the map.

Table 12

Frequency and Percent of Human-Computer Interactions by Duty Position

Function Subfunction	Commander		Battlespace Manager		Information Manager		Effects Manager	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Move	---	---	28	9.1	27	8.0	---	---
Move Ground Assets	---	---	28	9.1	---	---	---	---
Move Air Assets	---	---	---	---	27	8.0	---	---
See	101	96.2	189	61.2	304	89.9	188	64.6
Manipulate Map	11	10.5	18	5.8	6	1.8	91	31.3
Use Visualization Tools	6	5.7	29	9.4	26	7.7	12	4.1
Display Sensor Data	45	42.9	66	21.4	102	30.2	62	21.3
Recognize Targets	1	1.0	2	0.6	37	10.9	1	0.3
Assess Battle Damage	9	8.6	42	13.6	132	39.1	4	1.4
Summarize Situation Awareness (SA)	29	27.6	32	10.4	1	0.3	18	6.2
Strike	4	3.8	90	29.1	7	2.1	103	35.4
New Features	---	---	1	0.3	---	---	19	6.5
Designate Target	---	---	41	13.3	1	0.3	28	9.6
Fire Weapon	---	---	46	14.9	1	0.3	32	11.0
Monitor Fires	4	3.8	2	0.6	5	1.5	24	8.2
Other	---	---	2	0.6	---	---	---	---
Total	105	100	309	100	338	100	291	100

Move Function. During Run 10 execution, 55 of the 1,043 interactions (5.3%) were performed to move assets of the Unit Cell. To move ground assets, the Battlespace Manager performed a total of 28 interactions. These interactions involved deleting previously entered routes and entering new route points by clicking locations on the map. Platform moves entailed selecting menu options to start, halt, or resume their planned routes. Movement of air assets involved the performance of 27 separate interactions by the Information Manager to select reconnaissance targets and areas. Air asset movement routes were created by either clicking on a target or area icon, or by selecting a target or area from a menu.

See Function. The majority (75.1%) of interactions performed supported the See function, and involved managing the display of map and sensor assets. Table 12 shows that Manipulation Map tasks (i.e., Zoom and Scroll interactions) were performed frequently by the Effects Manager (91 interactions), but less frequently by the Cell Commander, Battlespace, and Information Managers. The Plot Intervisibility tool was not used in Run 10, however, the Heads Up Display (HUD) was used by all members of the command group.

Display Sensor Data interactions included 255 cursor moves over displayed icons (enemy, friendly, and groups of multiple platforms) to access "Properties" information. Typically, Properties information included the type and exact location of vehicles. Command group players performed 41 interactions in support of Recognize Targets, or Human Target Recognition (HTR), that involved display and refinement of images, and updating icons to reflect target type. Similarly, the players performed 187 interactions in support of Assess Battle Damage, or Battle Damage Assessment (BDA), that also involved the display and refinement of images, and updating icons to reflect target damage.

Strike Function. Results reported in Table 12 show that the Strike function was accomplished through the performance of 204 of the 1,043 total interactions (19.5%). Strike related interactions were performed almost exclusively by the Battlespace Manager and Effects Manager. Target Designation accounted for 70 interactions: 41 by the Battlespace Manager, 28 by the Effects Manager, and 1 by the Information Manager. Fire Weapon actions included 79 interactions: 46 by the Battlespace Manager, 32 by the Effects Manager, and 1 by the Information Manager. Seventeen (17) interactions were performed to Monitor Fires for LAM missile engagements by the Effects Manager, which involved moving the cursor over the LAM icon to bring up the Properties window. Monitor Fires for PAM missile engagements included seven interactions by the Battlespace, Information, and Effects Managers.

Other. The "Other" category was included to capture unanticipated and off-task activities. The only HCI task documented in this category was Reboot System, which involved selecting the reboot option and waiting for the system to reboot after a crash. Only two instances of Reboot System occurred during Run 10 execution, both by the Battlespace Manager.

Frequency of HCI by Function and Time. It may be useful to identify whether patterns of interaction changed across different portions of run execution. Figure 19 provides a comparison of the frequency of interactions performed across Run 10 by Function and Time (time quartiles = 21 minutes).

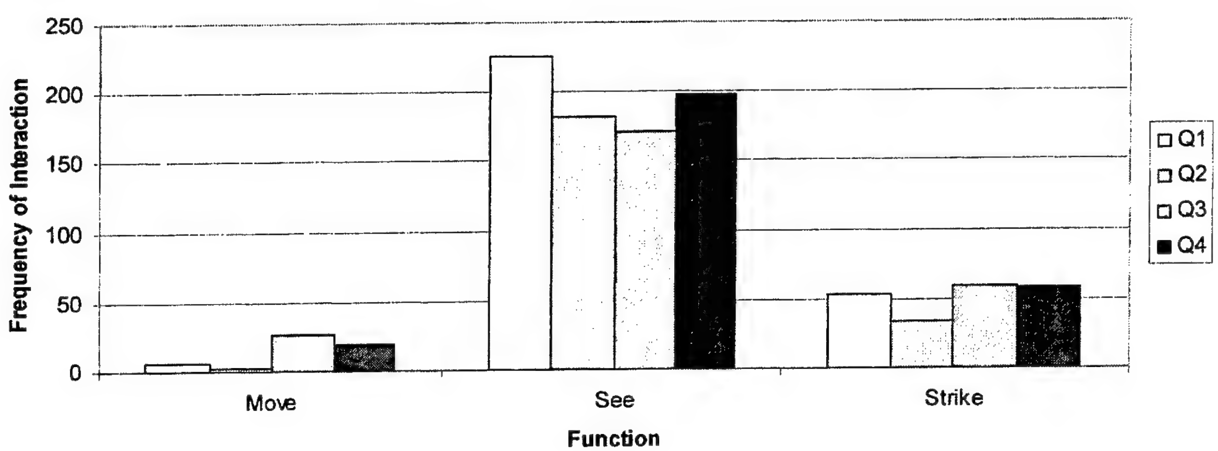

Figure 19. Frequency of HCI by Function and Time Quartile, Run 10 Execution.

Move related tasks represented 5.3% of the interactions during Run 10, with very few interactions during the first two quartiles prior to the launch of the ground forces. The majority of tasks performed (74.4%) were See related interactions that ranged from a high of 226 during the first quartile, to a low of 171 during the third quartile. Finally, 19.6% of the interactions performed represented Strike interactions. Strike interactions showed a slight decrease in the second quartile after planned and AGM fires had taken place, followed by a rise during the third and fourth quartile as ground forces advanced along an avenue of attack.

Task Allocation. Figure 20 summarizes how HCIs were performed at each screen and at each duty position during Run 10 execution. Notably, the two screens at each workstation are equivalent and redundant. Each command group player can choose which information windows to display and which tasks to perform on each screen. Overall, the number of interactions performed ranged from a high of 268 on the Battlespace Manager's right screen, to a low of 39 on the Battlespace Manager's left screen. The Battlespace Manager and Effects Manager performed most Strike related interactions, while the Cell Commander and Information Manager primarily performed See related interactions under Sensor Data Display, HTR and BDA.

Figure 20 also indicates player's screen preference for task performance. Clear screen preferences were the left screen by the Effects Manager, and the right screen by the Battlespace Manager. The Commander and Information Manager used both screens with approximately equal frequency to perform tasks. Functions were not exclusively allocated to screens. For example, the Battlespace and Effects Managers performed Strike related tasks on both screens.

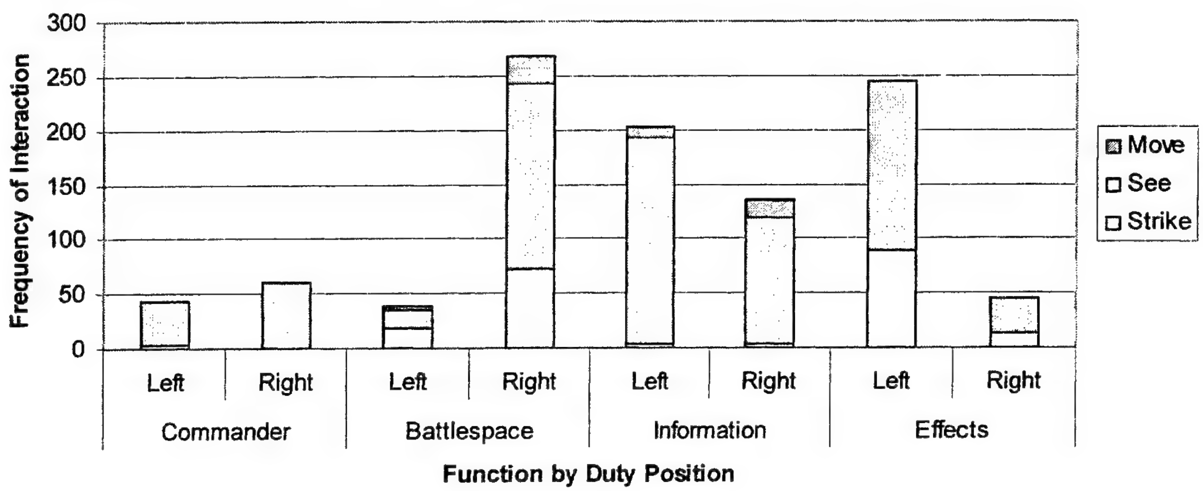

Figure 20. Frequency of HCI on left and right screens by Function and Duty Position, Run 10 Execution.

Duty Position Workload. In estimating workload, task frequency, duration and errors should all be considered. Given the low rate of time-consuming tasks and performance errors, task frequency was used as the primary criteria for estimating HCI duty position workload. Figure 21 illustrates the trend of HCI performance for each player during Run 10 execution by presenting the frequency of task performance in successive 10-minute intervals, or blocks of execution time. Note, the final time segment (80-84 minutes) was deleted from Figure 21 to

avoid misleading comparison across different time intervals. The data provided in Figure 21 represents an emerging empirical basis for task allocation among the command group, and between the command group and future C^2 systems.

A narrative description of the command group player's HCI tasks performed at each 10-minute interval of Run 10 was developed to further document how tasks vary over time during run execution (see Appendix G). A narrative summary of the information available in Appendix G is provided below:

- *Cell Commander.* Commander's interactions were almost exclusively (96.2%) See related interactions. The Commander performed 105 interactions during Run 10 execution, with the greatest number occurring during the 0-10 and 60-70 minute time intervals. During these intervals, the Commander was heavily involved in Display Sensor Data tasks that involved cursoring over both enemy and friendly icons to read properties information. Commander's lowest HCI workload occurred during the 30-40 minute time interval in which he performed no interactions.
- *Battlespace Manager.* The Battlespace Manager performed (309) interactions distributed across Move (9.0%), See (60.3%), and Strike (29.0%) functions. Greatest workload occurred early in Run 10 execution when he was heavily occupied in Display Sensor Data tasks, and Manipulate Map tasks (e.g., Zoom and Scroll). Workload appeared to decline to its lowest level in the 40-50 minute block during which he fired the LOS weapon system.
- *Information Manager.* The Information Manager performed more interactions (338) than any other command group player. Interactions included both See (89.7%), and Move (8.0%) Functions. Frequency of task actions peaked during the 40-50 and 70-80 minute time intervals corresponding to high levels of Display Sensor Data tasks, such as cursoring over enemy/friendly icons to read properties, and BDA tasks. Workload dropped late in the Run, during the 50-60 minute time interval when the Information Manager performed a lesser number of Display Sensor Data and BDA tasks, as well as some Move Air Assets tasks.
- *Effects Manager.* The Effects Manager performed 291 interactions supporting both See (64.6%) and Strike (35.4%) C^2 Functions. Highest workload occurred in (a) the 10-20 minute time segment of the run, predominantly Manipulate Map interactions, and (b) during the 70-80 minute time interval while performing Display Sensor Data interactions, firing the Netfires system, and Selecting/Changing Window display areas. Workload reached its lowest point during the 40-50 minute time interval during which he performed a low number of Display Sensor Data tasks that involved cursoring over map icons of vehicles to access information on both friendly and enemy assets.

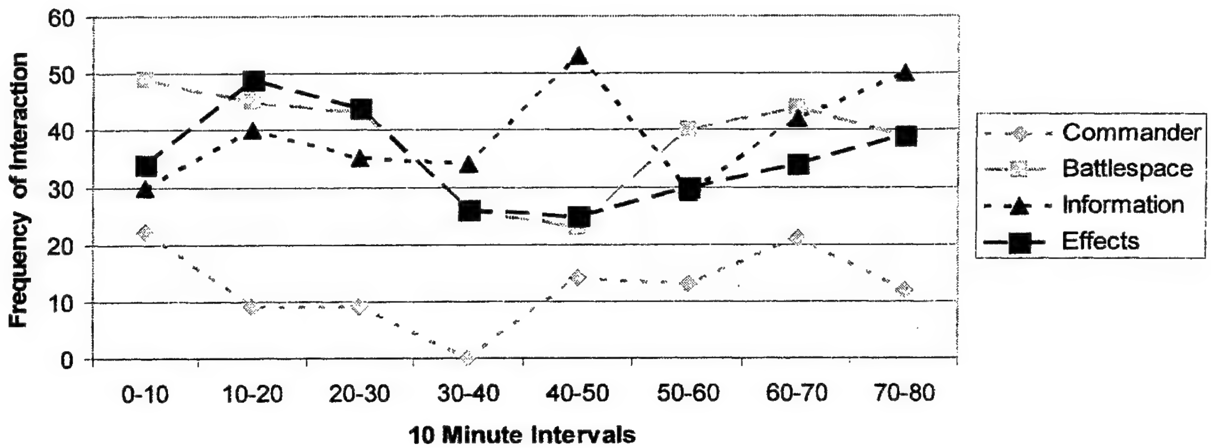

Figure 21. Duty Position HCI load by Time, Run 10 Execution.

HTR and BDA Workload and Task Allocation. Recognize Targets and Assess Battle Damage, more commonly referred to as HTR and BDA, were singled out for assessment. During Experiment 2, tasks supporting HTR and BDA were performed frequently, were time consuming, and showed evidence of collective (and possibly redundant) performance. Collective HTR and BDA performance refers to the situation where two or more command group players examine the same target image at approximately the same time in an effort to reach consensus, such as in identifying the type of target, or assessing target battle damage. Multiple reviews of the *same* target image by the same, or different, members of the command group might also indicate redundant performance. The HTR and BDA tasks required clicking on a picture icon on the map display, or choosing a picture from a menu list to bring it up on a display for review. Once brought up the operator used image location and resolution controls to select a portion of the picture and adjust contrast to enhance the image for review.

During Experiment 3's execution phase, 109 target images were viewed/reviewed across the four workstations. Six of these images were reviewed for HTR (5.5%), and 103 images reviewed for the purpose of BDA (94.5%). Target images were also shared on the overhead HUD screen on 11 occasions. Imagery analysis was relatively time consuming compared to most HCI tasks, requiring an average of 17.0 seconds for HTR, and 18.2 seconds for BDA assessment. Figure 22 presents the frequency of sensor image review at each workstation for purposes of HTR and BDA. The Information Manager was the primary image viewer, performing 72 HTR/BDA tasks. The other command group players performed fewer HTR/BDA imagery review tasks: Battlespace Manager 24 images, Commander 9 images, and the Effects Manager 4 images.

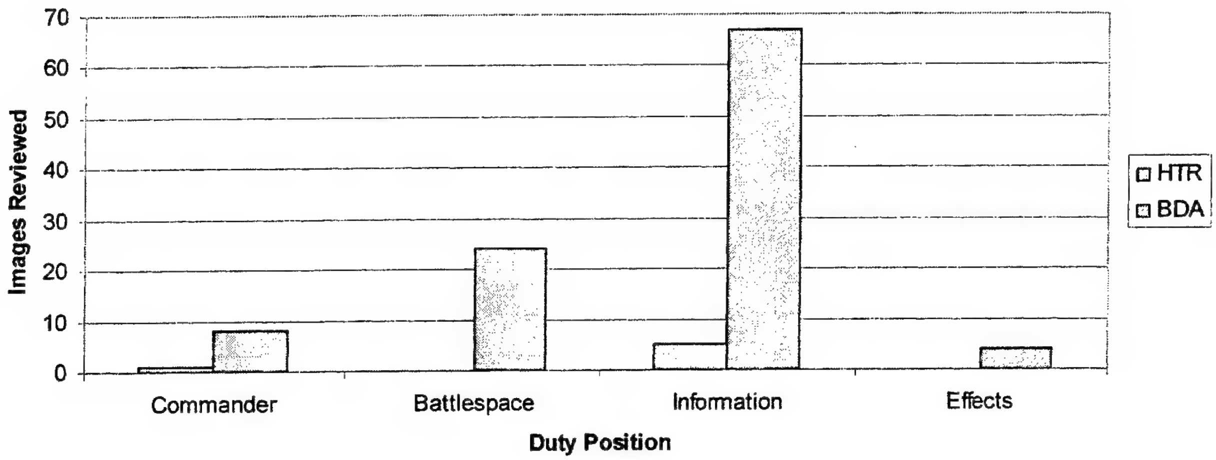

Figure 22. Number of sensor images reviewed by Duty Position, Run 10 Execution.

On occasion, the same sensor image was reviewed at more than one workstation while performing Display Target Images, suggesting shared (or redundant) task performance. Of the total of 109 images reviewed, 17 (15.6%) were reviewed at more than one workstation. The Battlespace and Information Manager reviewed 10 of the same images, the Commander and Information Manager reviewed 3 of the same images, the Effects and Information Manager shared in the review of 3 images, and the Commander, Battlespace Manager, and Effects Manager all shared in the review of one sensor image. On eleven occasions, command group players collectively reviewed target imagery presented on the HUD, as noted previously.

Notably, multiple reviews of *same* images during Experiment 3 were substantially less than during Experiment 2, respectively *15.6% versus 61.6%.* Credit for this workload reduction goes in large to design changes in the C^2 prototype to provide an audit trail on images reviewed and by whom. This is the type of information processing assistance readily performed by computers to improve the efficiency and effectiveness of command group performance, particularly for human intensive tasks such as HTR and BDA.

Human-Computer Interactions—Planning Phase

Analysis of HCI during the planning phase was introduced for Experiment 3, Run 10. The planning phase typically occurs immediately prior to the execution phase, and lasts approximately one hour. The ARI's decision to examine HCI during planning was based on two primary considerations. First, the evolving concept of FCS command and control stresses the requirement for more effective and collaborative planning methods before and during execution. By design, the planning process and products prior to execution provide the basis for planning changes during execution, sometimes referred to as dynamic re-planning. Second, planning for a manned and *robotic* force, such as the Unit Cell, requires substantial changes in the planning process and products required for execution.

A small command group with robotic elements becomes "doers" as well as thinkers. In essence, the command group must reformulate battle commands into computer commands.

More succinct verbalizations—such as commander's intent and guidance—with many implied tasks, must be issued in computer-mediated/dictated formats in which many tasks must be explicitly and precisely defined. Directing and controlling robotic elements through human-computer interaction entails many new tasks and many of the new C^2 prototype features used by the participant command group in Experiment 3.

Examination of new features and tasks during planning is particularly important. For as new features become increasingly automated or "hands-free" during execution, many of the new tasks associated with these features are performed primarily, *sometimes only*, during planning. By Experiment 3, the C^2 prototype used by the command group included an array of highly automated features that supported each of the basic C^2 functions under investigation. A few examples are noted here, many more are provided in the results that follow. For the Plan function, a Rehearse Plan tool allowed the Commander and other members of the command group to review a quick-time animation of their planned movements by ground and air assets. For See, the Information Manager or others could establish Auto-Reconnaissance routes and parameters. For Move, the Battlespace Manager or others could use a Create Routes function that automatically generated route waypoints based on mobility and intervisibility calculations. For Strike, the Effects Manager or others could set the Attack Guidance Matrix to automatically fire at high priority targets during execution.

Limitations to the HCI analysis of planning that impact the results are noted. Some of these limitations also affected the verbal analysis, as discussed. Planning communications and activities by the command group were often limited in latter runs, including Run 10, as the command group had performed very related planning on prior runs. For example, planning with respect to Terrain was curtailed by the command group's prior experience with the NTC terrain database during 30+ experimental runs (Experiments 1-3), and the players' live rotations at NTC. Therefore, the command group routinely re-used many of the same graphic control measures (GCMs) in planning that they had used during earlier runs. More specifically, the following GCMs were already input in their C^2 prototypes at the beginning of Run 10 planning: 7 attack routes, 5 phase lines, 4 named areas of interest, 12 friendly vehicles and infantry dismounts, and 10 Unattended Ground Sensors (UGS). Notably, the C^2 prototype's ability to store prior plans, including GCMs and player-selected settings for automated features such as AGM, is in general a very useful capability.

In addition, the Information Manager assigned for Runs 6-11 had replaced the original Information Manager, and the Effects Manager was absent for approximately 30 minutes of the planning phase. Estimating the impact of such personnel disruptions is difficult. However, the Commander appeared to accept and perform some of the tasks typically performed by the original and more experienced Information Manager. Finally, all results and conclusions are limited by ARI's HCI analysis of only one experimental planning phase.

The primary measures used for assessing HCI performance were task duration and frequency, as for execution. Overall, the frequency as well as the type of HCI tasks performed differed across the command group, as expected. Task frequency and type also differed within duty position in a comparison of tasks performed on left versus right display screens by each player. Time and error measures were less useful as performance criteria. Performance times

for most HCI planning tasks were typically 5 seconds or less in duration, and relatively few "errors" in HCI performance were detected. The only tasks associated with errors were inadvertent clicks on GCMs, two instances of accidentally dropping an icon back to its original menu location, and one example of placing an incorrect unit icon on the map (squad instead of platoon).

Task Duration. Time duration for task completion was examined to assess HCI task performance and identify potential training requirements. Tasks requiring longer performance times could be candidates for redesign, machine aiding, or additional training. Task performance time was estimated by identifying Start and Stop actions, typically involving the selection of a menu option, or opening and closing a window. Overall, during Run 10 planning the command group players performed 499 individual interactions, less than 50% of the1,043 interactions recorded during execution. Approximately 31% of these planning interactions (153 of the 499) required more than 5 seconds to perform. Frequency data and mean performance times for the ten most frequently performed long duration tasks (133 of the 153) are presented in Table 13.

Notably, the same task types listed in Table 13 were sometimes more quickly performed, and required less than 5 seconds. For example, the time required to drag/drop icons varied considerably. Accordingly, Table 13 reports only the 26 occasions in which the Commander took longer than 5 seconds to drag/drop icons. In fact, the Commander performed this task 70 times during the planning session, but on the other 44 occasions the Commander took less than 5 seconds to drag/drop an icon.

Table 13

HCI Long* Duration Tasks by Frequency and Time, Run 10 Planning

Function Task	Frequency and Task				Time in Seconds (Mean/SD)
	Commander	Battlespace	Information	Effects	
Plan					
Place Platforms on Map	1	---	9	---	16.7/12.3
Rehearse the Plan	---	6	7	---	28.8/13.4
Move Icons (Drag/Drop)	26	3	13	---	14.7/13.0
Modify Overlay Graphics	1	---	7	---	21.4/19.8
Move					
Create Ground Routes	---	6	---	---	22.0/8.6
Create Air Routes	---	---	21	---	21.1/11.1
See					
Plot Intervisibility	---	14	---	---	22.6/13.5
Select/Change Windows	---	1	4	---	20.8/13.0
Change Icon Type	1	---	6	2	18.0/12.0
Strike					
Fire PAM	---	---	---	5	13.2/4.7

*Long duration tasks require more than five seconds to perform.

Frequency by C^2 *Function and Duty Position.* Figure 23 provides a summary overview of the HCI tasks performed by C^2 Function during Run 10 planning. Of the 499 total interactions performed during planning, their frequency by function was: Plan (179), See (256), Move (52), and Strike (12). As for execution, the greatest number of interactions performed during planning supported the command group's ability to See or visualize the battlefield, particularly the weapon system identities and characteristics of friendly and templated enemy assets. Table 14 presents an overview summary of the task frequency data for the 9 of 17 C^2 Sub-Functions and the 26 of 83 HCI tasks available that were actually performed during Run 10 planning. A brief narrative summary of these results by C^2 Function is provided below.

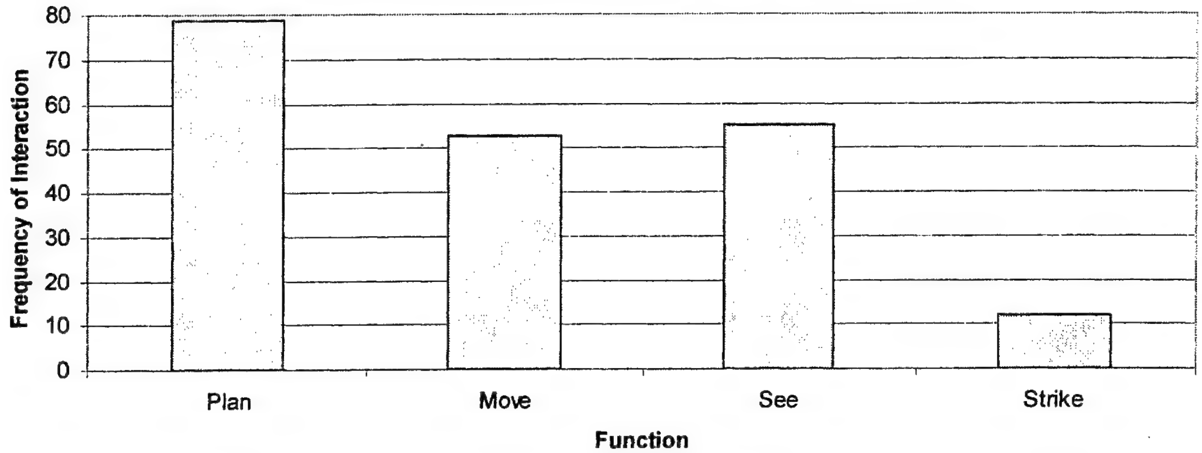

Figure 23. Frequency of HCI by C^2 Function, Run 10 Planning.

Table 14

Frequency of C^2 Sub-Functions and HCI by Duty Position, Run 10 Planning

Function / Subfunction / Task	Commander		Battlespace Manager		Information Manager		Effects Manager	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Plan	76	63.3	42	25.8	60	35.7	1	2.1
Create Mission/COA	76	63.3	42	25.8	60	35.7	1	2.1
Create Overlay Graphics	---	---	1	.6	---	---	---	---
Place Platforms on Map	1	38	---	---	14	8.3	---	---
Rehearse the Plan	4	3.4	10	6.1	8	4.8	---	---
Move Icons (Drag/Drop)	70	58.3	21	12.9	28	1.7	1	2.1
Modify Overlay Graphics	1	.8	10	6.1	10	6.0	---	---
Move	---	---	25	15.3	26	15.5	1	2.1
Move Ground Assets	---	---	24	14.7	5	3.0	1	2.1
Create Routes	---	---	7	4.3	---	---	---	---
Edit Existing Route	---	---	4	2.5	---	---	---	---
Delete all Tasks	---	---	8	4.9	5	3.0	1	2.1
Create Overwatch Task	---	---	1	.6	---	---	---	---

Table Continues

Generate Route	---	---	4	2.5	---	---	---	---
Move Air Assets	---	---	---	---	21	12.5	---	---
Recon an Area	---	---	---	---	21	12.5	--	---
Group Follow	---	---	1	.6	---	---	---	---
Create Ground Follow	---	---	1	.6	---	---	---	---
See	44	36.7	96	58.9	82	48.8	34	7.08
Manipulate Map	10	8.3	10	6.2	15	8.9	18	37.5
Zoom Map	8	6.7	6	3.7	12	7.1	7	14.6
Scroll Map	2	1.6	4	2.5	3	1.8	11	22.9
Use Visualization Aids	6	5.0	47	28.8	14	83	2	4.2
Plot Intervisibility	---	--	27	16.6	---	---	---	---
Display on Heads Up	---	---	2	1.2	---	---	---	---
Select/Change Windows	6	5.0	11	6.7	14	8.3	2	4.2
Change GCM Settings	---	---	7	4.3	---	---	---	---
Display Sensor Data	26	21.7	39	23.9	44	26.2	12	25.0
Query Enemy	17	14.2	10	6.1	31	18.5	7	14.6
Query Friendly	9	7.5	27	16.6	13	7.7	5	10.4
Toggle Sensor Fans	---	---	2	1.2	---	---	---	---
Recognize Targets	2	1.7	---	---	9	5.4	2	4.2
Change Icon Type	2	1.7	---	---	9	5.4	2	4.2
Strike	---	---	---	---	---	---	12	25.0
Fire a Weapon	---	---	---	---	---	---	12	25.0
Fire LAM	---	---	---	---	---	---	3	6.3
Fire PAM	---	---	---	---	---	---	6	12.5
Fire LOS	---	---	---	---	---	---	1	2.1
Delete Fire Tasks	---	---	---	---	---	---	2	4.2
Total	120	100	163	100	168	100	48	100

- *Plan Function.* For Run 10 planning, 179 of the 499 total interactions (35.87%) were performed to support the Plan Function. These interactions primarily involved moving existing vehicle icons and graphic control measure lines (120 interactions) into their initial starting positions on the tactical map using the drag/drop icons interface capability. The Rehearse Plan tool was used by the Commander, Battlespace, and Information Managers a total of 22 times to observe and compare the planned movement of both ground and air vehicles, and dismounted Land Warrior teams. In particular the Rehearse Plan tool was used by the Battlespace Manager to brief the Commander regarding the planned movement of ground assets.
- *See Function.* The majority (51.0%) of Run 10 planning interactions supported the See function. The most frequent See activities involved using the Query Enemy/Friendly tool, cursoring over vehicle icons to bring up Enemy (65 interactions), and Friendly (54 interactions) asset properties information such as the type, and exact position of vehicles. The use of the Plot Intervisibility tool was also a frequently used feature (27 interactions) in planning ground asset movement routes.
- *Move Function.* The Move function was accomplished through the performance of 52 of the 499 total (10.6%) interactions. These Move related interactions involved creating future ground and air vehicle movement routes, typically by entering route points and by clicking

locations on the map. The Battlespace Manager performed 25 interactions associated with creating routes for ground vehicles, and the Information Manager performed 21 interactions to create routes for air sensor assets.

- *Strike Function.* Only 12 interactions recorded for Run 10 planning supported the Strike function, all performed by the Effects Manager. The relatively low number of Strike-related interactions during planning may reflect the introduction of the AGM that provided automated fires against a number of operator-defined target contingencies. As no AGM tasks were recorded during the planning phase for Run 10, the AGM settings from Run 9 were probably used to begin the execution phase of Run 10. As noted, the low number of HCI interactions related to Strike may have resulted from the Effects Manager being absent from the C^2 vehicle for approximately 30 minutes during Run 10 planning.

Figure 24 provides a summary overview of the interactions performed by duty position during Run 10 planning. In order by amount, the percentage of See related interactions performed by each player was Effects Manager (70.8% of his total tasks), Battlespace (58.9%), Information Manager (48.8%), and Commander (36.7%). Interactions supporting the Plan function were the next most frequently performed. Of the total interactions performed by each player, the percentage of Plan related interactions by position were: Commander (63.3%), Information Manager (35.7%), Battlespace Manager (25.8%), and Effects Manager (2.1%). Move related interactions were less frequent and performed primarily by the Information Manager and the Battlespace Manager, respectively 15.5% and 15.3% of their total interactions. Only 12 instances of Strike related HCI tasks were recorded, all performed by the Effects Manager, representing 25% of his total interactions during planning.

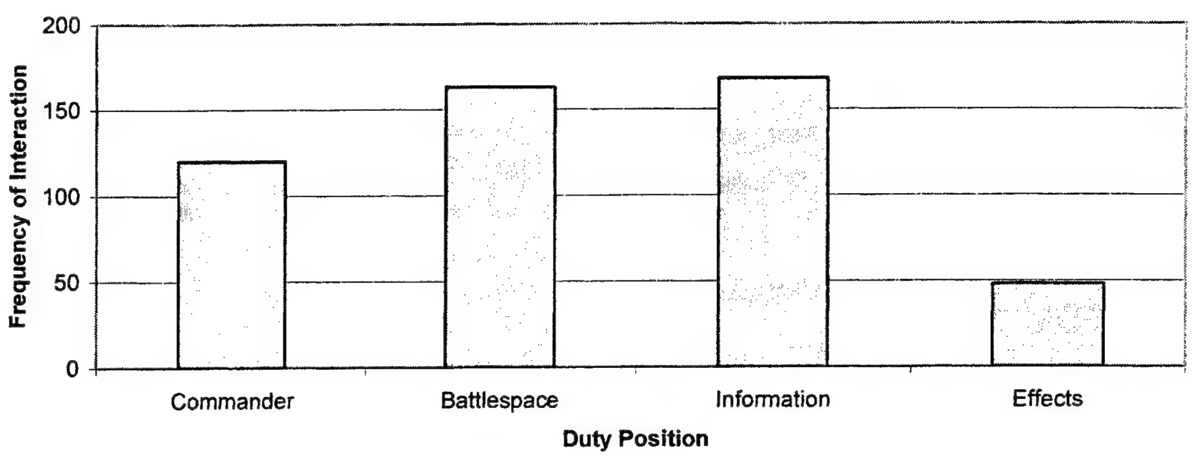

Figure 24. Frequency of HCI by Duty Position, Run 10 Planning.

The most frequent interactions performed by the Commander were to Create Mission/ Course of Action (COA) (76 interactions), and Display Sensor Data (26 interactions). The Commander performed Create Mission/COA tasks primarily to move existing vehicle and GCMs on the map display, to modify existing graphics, and to rehearse the plan. The Commander performed Display Sensor Data tasks primarily to access the properties of enemy icons. The most frequent interactions performed by the Battlespace Manager were Use Visualization Aids (47 interactions), Create/Update Course of Action (COA) (42 interactions), and Display Sensor

Data (39 interactions). The most frequent interactions for the Information Manager were Create Mission/COA (60 interactions), Display Sensor Data (44 interactions), and Move Air Assets (21 interactions) by creating routes. The most frequent interactions for the Effects Manager were Manipulate Map (18 interactions) that primarily involved Zoom and Scroll tools, Display Sensor Data (12 interactions), and the use of the Fire Weapon tool (12 interactions) to plan fires for the PAM and LAM missiles, and the LOS gun.

Task Allocation and Workload. Task allocation and workload during the planning phase by FCS-type small command groups are important and largely neglected issues. These issues are at best only indirectly addressed by the results provided in this section. The ARI's prior caveats about the exploratory nature of this report's planning results apply especially here. Brief narrative descriptions provided below highlight task allocation and workload issues. These descriptions provide a coherent summary of key interactions performed by each command group player during Run 10 planning.

- Commander. The C^2 prototype provided a shared view of the planning process and products (such as icon emplacement, route generation and terrain consideration) that enabled the Commander to monitor the inputs of other players and correct mistakes early. For example, "You've got the wrong unit there, it should be a platoon size element." The C^2 prototype provided redundant capabilities across duty positions. This allowed the Commander to emplace enemy templates and unmanned ground sensors, so the Information Manager could focus on creating and updating named areas of interests (NAIs). Drag/drop placement of UGS was a time consuming task. The Commander first placed UGS in general areas, then zoomed to high magnification to adjust placements based on his best estimate of enemy routes. In particular, the Commander provided over-the-shoulder guidance to players, and used the Rehearsal tool to discuss the plan with other players.
- Battlespace Manager. The Battlespace Manager used the HUD to present his plan of movement to the Commander: "So this is my route plan." Presentation included showing vehicle intervisibility as he moved his cursor along the planned movement route, identifying a templated tank that had to be engaged, and using the Plot Intervisibility tool to show unrestricted visibility across the valley. This presentation included verbal brief of the route plan to the Commander. He used the HUD to demonstrate sensor coverage for the Commander by using the Toggle Range Fans tool while explaining: "This is direct vision optics (DVO) and infra red (IR). I can turn the Fire Finder fan on. We are going to be able to see out to here." By using the HUD, the Effects Manager was able to comment on the Battlespace Manager's plan by identifying the location of planned PAMs and LAMS against targets. The Battlespace Manager used the Rehearse Plan tool to create and refine automated routes, confirming that vehicles would move as desired in the group follow mode, and working with the Commander to identify needed adjustments.
- Information Manager. The Information Manager performed numerous drag/drop placements of enemy icon templates and numerous, mainly fruitless, queries on enemy templates. The Information Manager often used the Rehearsal tool after creating movement routes for the Shadow and the four Micro-UAVs to confirm desired routes had been entered. In particular, air routing and imagery analysis tasks contributed to his workload. As stated to the Commander: "I have two Micro-UAVs taking pictures of every one of those templated

targets out there. Then I will have one for NAI 1, and one for NAI 2. Can have Micro-UAV2 or Micro-UAV3 looking at the routes."

- Effects Manager. Prior to his absence, the Effects Manager created some firing tasks, observable as missile fly-outs during rehearsals run by the command group, particularly the Commander. The AGM appeared to shift the allocation of some Strike task decisions to automation, particularly for high priority targets, and reduce the overall human requirement to plan and set fires. As noted, the Effects Manager did not revise the AGM during Run 10 planning. In addition, automated features such as AGM may help reduce personnel requirements, at least temporarily. When faced with starting Run 10 execution without the Effects Manager, the Commander commented that he could assume the Effects Manager tasks temporarily: "Well, initially with the AGM and everything, I could do the quick fires."

Table 15 provides a bulleted summary of the same HCI tasks performed by each command group player during Run 10 planning.

Training Implications. Human performance during the Planning phase needs to be more closely and rigorously examined. At best, planning results should provide valuable insights into training requirements based on task identification and task allocation. Notably, many key and time consuming tasks—such as creating and verifying vehicle air and ground routes, planning and verifying automated fires, and intelligence planning and preparation—are performed during planning. Training implications are discussed in more detail in the Conclusions section.

Table 15

Key Planning Functions and Tasks by Duty Position, Run 10 Planning

Cell Commander	Battlespace Manager	Information Manager	Effects Manager
See and understand the battlefield. Develop, prepare, and synchronize COAs. Create routes for C^2 Vehicle. Emplace Threat Icon Templates on C^2 map.	Plan ground sensor routes, overwatch positions, and employment of two LOS weapons. Create routes, group follow, and overwatch taskings for: Line of Sight Vehicle (2) Roboscout Vehicle (2) Future Warrior Vehicle (2) Future Warrior Team (2) Javelin Team (2)	Develop Intelligence collection plan with NAIs to identify enemy COA. Create routes for Shadow UAV and four Micro-UAVs. Create area/target reconnaissance tasks and picture taking tasks for UAVs.	Plan LAM and PAM fires for (2) Netfire systems. Create Netfire ground routes. Create/update the Attack Guidance Matrix (AGM)

Automated Measures Validation and Refinement

As preface, the development and validation of automated measures is an iterative process. This process generally requires the collaborative efforts of behavioral, technical, and operational subject matter experts. Behavioral scientists often initiate the process by identifying, describing and defining the measures of interest. Technical experts then attempt to develop the measures specified, including the software codes required to identify and log the measures as defined. As will become clear in the results below, there are often discrepancies between behavioral inputs and technical outcomes. Resolving such discrepancies requires additional refinements, often by the behavioral and technical experts. Ultimately, operational experts must help determine the practical utility of the automated measures developed and validated.

The results provided below are basically a status report on the FCS C^2 program's efforts to develop and validate automated measures. Automated measures designed to automatically capture data on command group interactions with their C^2 prototypes to support training, evaluation and C^2 system design. Upon completion of the manual HCI analysis of Run 10, manually tabulated frequencies of command group-C^2 prototype interaction were compared with the three automated measures developed for Experiment 3.

Overall, the results are meager but promising. Two of the three automated measures developed for Experiment 3 were at least partially validated. Efforts to validate the measure Alert Acknowledged were not successful. As indicated in the list of requested measures in Table 5, the intent of this measure was to capture the *time to respond to an alert by turning it off.* However, the parsed files for Alert Acknowledged appeared to include unnecessary and confusing information. For example, time data included two, sometimes three, different time stamps that could not be readily distinguished or matched to the run times available with the video recordings used for manual data reduction. Images associated with some alerts were identified on the log with system file names (e.g. \\uc1-images\images\ir__10.ntf) versus the C^2 prototype image names (e.g., Garm 23) available with the video recordings. In addition, the C^2 prototype provides an array of options for setting and responding to alerts that complicates measure definition and extraction.

Efforts to validate the measures Images Requested/Viewed and Create Ground/Air Route were fairly successful. Table 16 summarizes the validation results with a comparison of the frequencies tabulated for these two measures by automated and manual measurement methods. There were no discrepancies in the number of images requested/viewed by the Commander and Effects Manager who accessed their images from the Battlefield Assistant in the *Alert* Window. However, there were notable discrepancies in this same measure for the Battlespace and Information Manager. These discrepancies were probably due to shortcomings in the developed measure that did not count images viewed by clicking Chaser round icons that only appeared on the *Map* Window.

Similarly, there were no discrepancies in the measured number of ground routes created by the Battlespace Manager. There was only a small discrepancy (19 versus 18) in the measured number of air routes created by the Information Manager. This appeared to be due to the fact

that manual measures tabulated only the number of air routes *actually* generated, rather than the number of air routes *attempted* but not successfully completed.

In sum, the results on the development and validation of automated measures are quite limited but promising. Discrepancies identified for Images Requested/Viewed and Create Ground/Air Route should be resolved with collaboration by behavioral and technical experts. Clearly, additional development, refinement and validation are needed to develop a useful set of automated measures to support training, evaluation and C^2 system design.

Table 16

Comparison of Automated Measures to Manual HCI Data Reduction

Duty Position Measured task	Frequency Accounted For Automated Measures	 Manual HCI Analysis
Commander		
Images Requested/Viewed	9	9
Battlespace Manager		
Create Ground Route	11	11
Images Requested/Viewed	2	24
Information Manager		
Create Air Route	19	18
Images Requested/Viewed	62	72
Effects		
Images Requested/Viewed	4	4

Subjective Measures

Results from subjective measures are based on the battery of measures developed and administered by ARI during Experiment 3. Overall, the results from 10 different survey and questionnaire instruments are reported. Most of these results were provided in the Rapid Reaction Report provided to the Program Manager (PM) FCS C^2 in November 2002. They are included here to provide the PM consolidated documentation on ARI's efforts for Experiment 3. This section begins with an examination of an informal interview conducted in the C^2 vehicle immediately after each run called the In-Place After Action Review (AAR).

In-Place After Action Review: In Their Own Words. The command group player observations and assessment during the In-Place AARs provides an informative summary of each run from Experiment 3 in the players' own words. These observations are of particular interest as they were recorded directly after each run, and reflect the command group's most immediate assessment of the just completed Unit Cell operations. The In-Place AAR documents specific issues and observations associated with each run from the players' perspective. A small sample of the observations provided by the four players during the In-Place AAR follows:

Battlespace Manager Comments:

- Run 8. I tried the Group Overwatch function. It worked in *planning*. It generated a decent route to move the cluster forward through first terrain box. It didn't work in *execution*. Robo-scout GSR (ground surveillance radar) went out alone, but others didn't follow. So FIFV (Future Infantry Fighting Vehicle) and dismounts not into the fight.
- Run 10. We had a good plan, and we are executing it well. But we can't tell if a target was killed until the AAR. We wanted to attack the enemy's strength. I'm not confident in Group Follow and terrain reasoning. The wrong vehicle was in the lead on the group follow task. We had a problem with the FIFV taking artillery.
- Run 11. Pretty happy. Individual route generation worked. We synched assets using the synchronization matrix. We dismounted the infantry and bounded forward.

Information Manager Comments:

- Run 8. Good run, sensors working. The problem was clutter. The graphics for BDA (battle damage assessment), Chasers, Targets, and Spot Reports are all stacked on top of each other. Message icon is black and I can't see through it to other information. Didn't have time to drill down through them. Tried to change target states, but it looked like AGM (attack guidance matrix) auto fired when state changed.
- Run 10. Biggest thing, the UAV's (unmanned aerial vehicles) are going out on their own. The Shadow took off on its own without me knowing about it. I got wrapped up in imagery and didn't realize how long it was taking. Same problem with micro-UAVs too, they went off on their own and I had to keep pulling them back.
- Run 11. We kept the Shadow alive, couldn't task the A160. Shadow discovered lots of targets. Very late lost some micro-UAVs. Named areas of interest not effective.

Effects Manager Comments:

- Run 8. Good run, hit a lot of stuff. Bad thing was that we hit the same targets repeatedly. loitering attack missile/munitions (LAMs) didn't do redirect. I need to work circular error probable (CEP) when engaging closely located targets.
- Run 10. Went fairly well. I tried to work on the problem of missiles guiding in on past targets. I tried different search radiuses, but kept on having the same problem of subsequent missiles guiding in on same target.
- Run 11. We shot a lot, 46 missiles, and got the unattended ground sensors (UGS) into the fight. We put up a wall of LAMs based on template of enemy air defense artillery (ADA). Auto redirect of LAMs worked when targets popped up. We need to watch this because the closest LAM didn't go to closest target.

Unit Cell Commander Comments:

- Run 8. Planning went well. Intelligence was pretty good. We lost the synthetic aperture radar (SAR) early, tasked the A160. I am more concerned that (1) precision attack missiles/munitions (PAMs) hit targets that were already hit, and (2) BDA is still a challenge for us, we keep double tapping targets. Will keep micro-UAVs right in front as we move.

- Run 10. Our plan to concentrate Intelligence worked. We are working at synchronizing systems, and working at developing tactics, techniques and procedures (TTP's). It is real hard to tell if we are hitting targets. We would do a double tap and still see target moving. BDA still missing.
- Run 11. We had good situational awareness. We tried to operational control (OPCON) the A160. The real winner today was moving target indicators (MTI). We used a tactical move, and our lesson learned is to conduct overwatch with the GSR. We need to learn, practice, and develop TTPs on how to OPCON the A160.

Workload and Performance Success. One key question for Experiment 3 was whether or not the addition of the new features into the C^2 prototype would alter player workload ratings. Figure 25 provides summary results on perceived workload across all Experiment 3 runs by duty position and Complexity. These workload ratings were calculated by averaging player ratings across Mental, Physical, Temporal, Effort, and Frustration scales. Overall, the figure depicts a clear increase in perceived workload in a comparison of Medium versus Too High levels of run complexity. This increase is not uniform across players; workload increase in the Too High runs was most pronounced for the Information and Battlespace Managers.

Figure 26 provides summary results on performance success across all Experiment 3 runs by duty position and Complexity. These ratings were based on responses to a question that asked players to rate "How successful were you in accomplishing what you needed to do?" after each run. All four players reported a decline in performance success in the Too High level of Complexity. The expected decline in performance success was greatest for the Information Manager and least for the Effects Manager. The Information Manager's lower estimates of performance success may reflect difficulties in controlling the Unit Cell's Shadow UAV and the Micro-UAVs, and large amounts of target imagery analysis required in the Too High condition.

C^2 Prototype Support of C^2 Functions and METT-TC Factors. Figure 27 provides summary results on the C^2 prototype's effectiveness for Plan, Move, See, and Shoot functions. Average estimates of the prototype effectiveness for C^2 functions ranged from "Neutral" to "Very Effective." Overall, the results indicate substantial room for improving the C^2 prototype, particularly for the See function. Different estimates by duty position should be noted. For example, ratings of effectiveness in support of Move differed considerably between the Cell Commander ("Neutral"), Battlespace and Information Managers ("Effective"), and Effects Manager ("Very Effective"). Written comments cited difficulties in accomplishing BDA and target declutter, and the ineffectiveness of Micro-UAVs for seeing the battlefield. Commander recommended adding intervisibility lines, and better mobility/counter-mobility graphics.

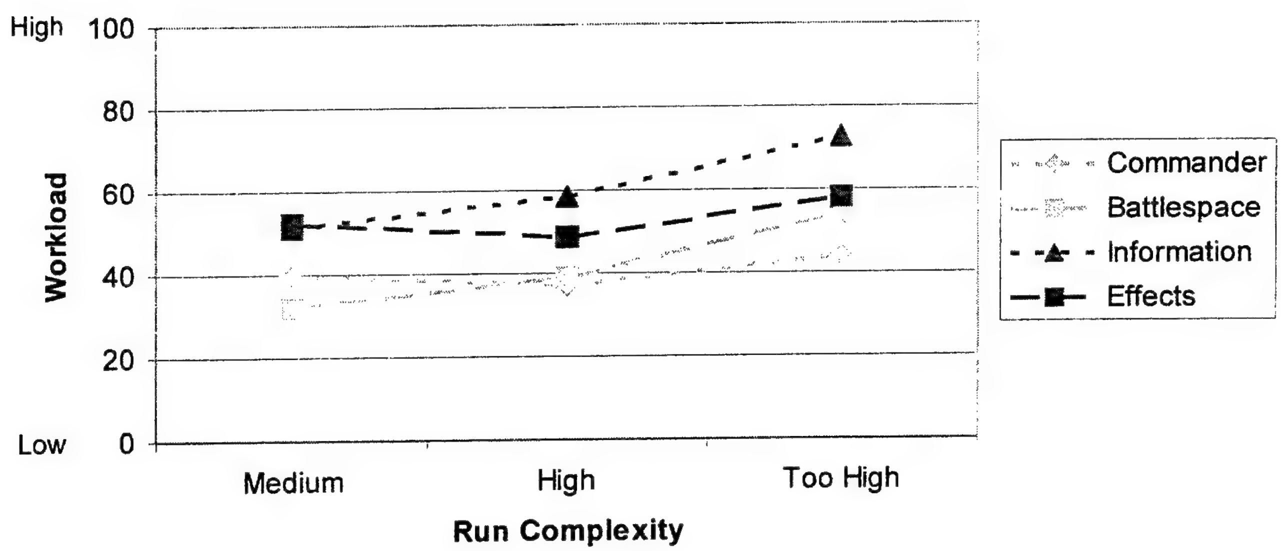

Figure 25. Average Workload Ratings Across Runs by Duty Position and Run Complexity.
Scale Values: 0 = Very Low, 50 = Moderate, 100 = Very High

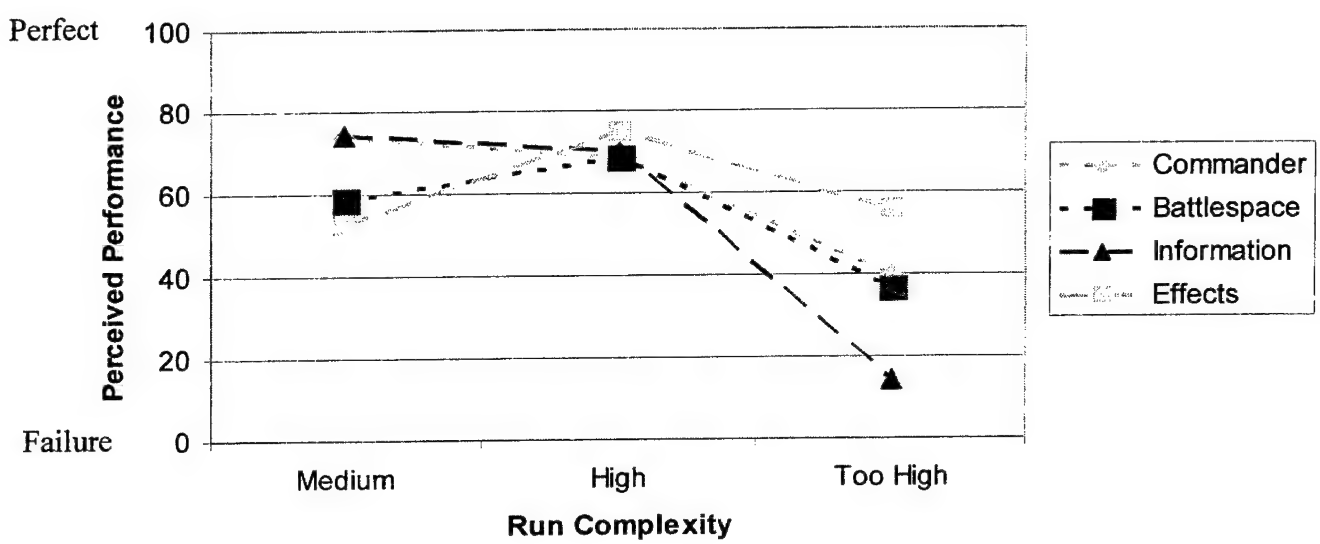

Figure 26. Average Performance Success Ratings Across Runs by Duty Position and Run Complexity.
Scale Values: 0 = Failure, 50 = Moderate, 100 = Perfect

Figure 28 provides summary results on the C^2 prototype's effectiveness for Mission, Enemy, Troops, Terrain, Time, and Civilians factors. Average estimates of the prototype effectiveness for these factors ranged from "Neutral" to "Very Effective." Overall, the C^2 prototype was rated "Effective" or better on 21 of 24 total ratings (85%). "Neutral" ratings

should be attended to, however. Written comments cited difficulties that led to targeting and engaging civilian or non-hostile vehicles.

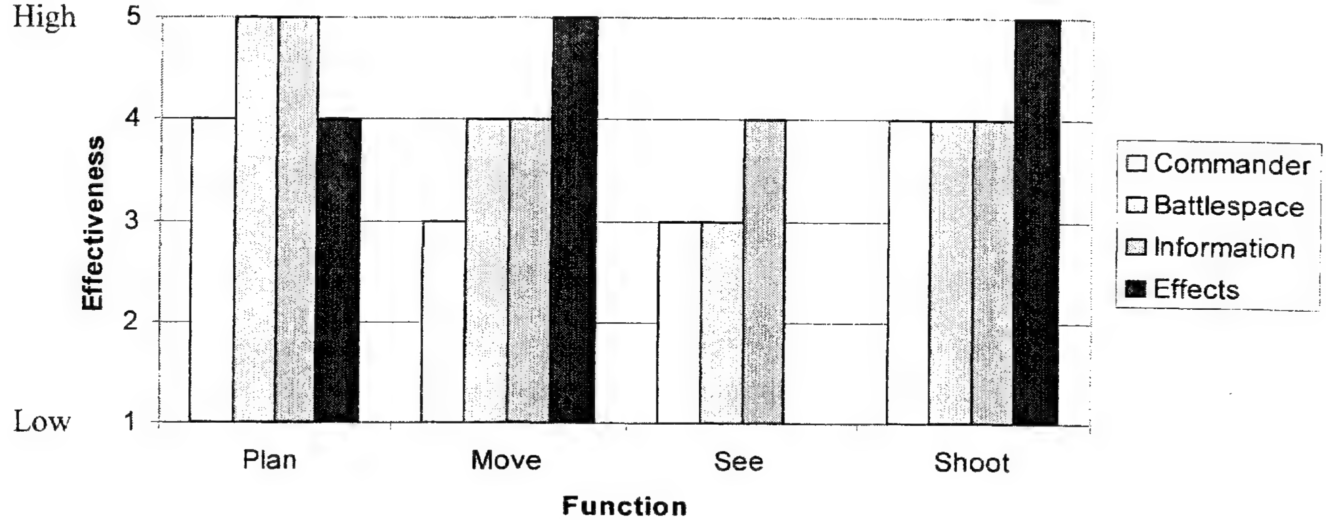

Figure 27. Mean Ratings of Effectiveness of C^2 Prototype by Function and Duty Position. Scale Values: 1 = Very Ineffective, 3 = Neutral, 5 = Very Effective; Run 11

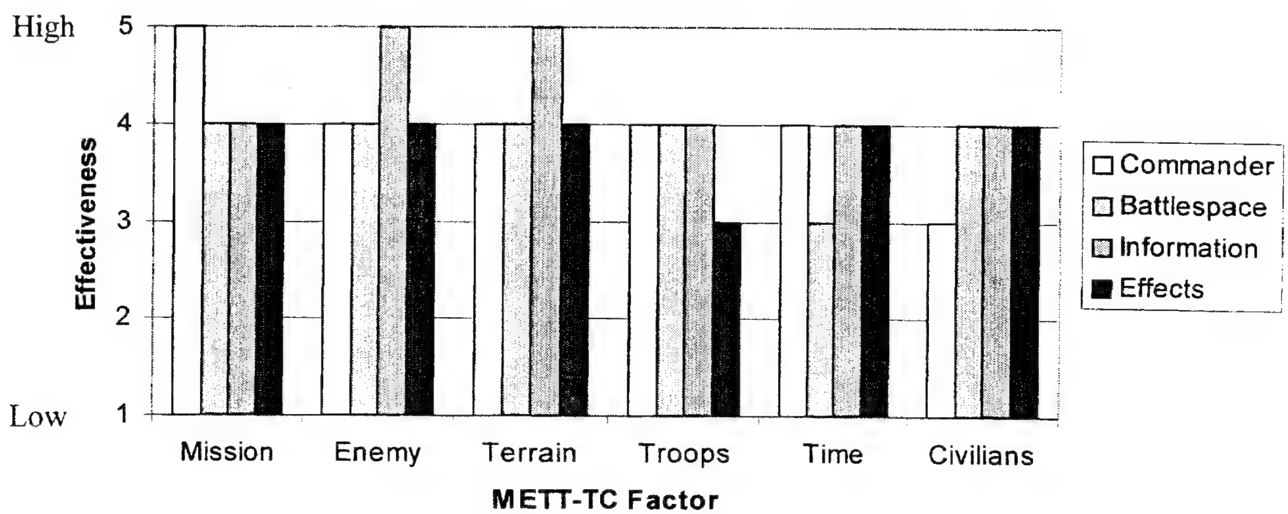

Figure 28. Mean Ratings of Effectiveness of C^2 Prototype by METT-TC Factor and Duty Position.
Scale Values: 1 = Very Ineffective, 3 = Neutral 5 = Very Effective; Run 11

Skill Proficiency. Figure 29 provides summary results on player ratings of skill proficiency. Ratings of skill proficiency prior to the experimental runs were generally lower than after-run ratings, as expected. Collective technical skills for using the C^2 prototype and directing robotic assets received the lowest ratings. Run experience clearly resulted in higher

ratings of skill proficiency in general. However, a pattern of increased proficiency with increased run experience was not strongly supported.

Two possible reasons why a pattern of increasing proficiency was not found are briefly examined. First, substitutions in personnel and reassigned duty positions across runs confound individual skill and particularly collective skill proficiency estimates. Second, "sometimes you don't know what you don't know." Perhaps, only as the players began to use and struggle with the new C^2 prototype features did they begin to realize the intricacies, complexities, and unexpected consequences of this automation.

At times, automation failed to perform as expected. At other times, it performed in unexpected and detrimental ways. Even during the latter runs of Experiment 3, the causes of the automation problems being experienced were often unclear. Was it a shortcoming in the technology, training, or TTPs? Often, no one on the operational or technical teams could precisely identify the exact cause of the automation problems experienced during Experiment 3. A similarly unclear pattern of results is provided in the following section on workload associated with new C^2 prototype features.

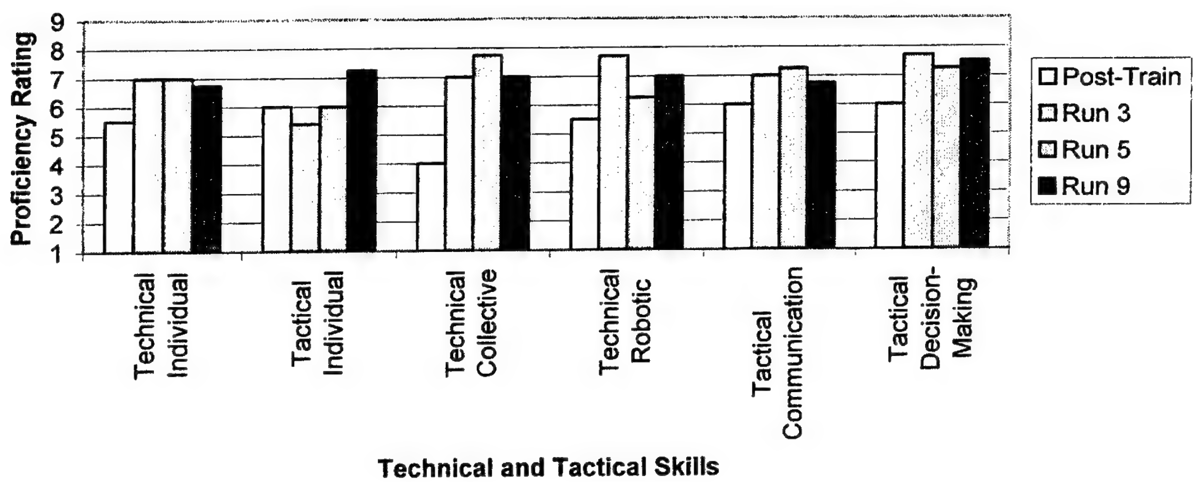

Figure 29. Command Group Player Proficiency Ratings of Technical and Tactical Skills. Scale Values: 1 = Extremely Low, 5 = Average, 9 = Extremely High

Workload on New C^2 Prototype Features. Figure 30 provides a summary of the results on average workload across players on selected new C^2 prototype features for Run 2 and Run 9. For clarity, scale values were reversed so that larger numbers are associated with higher workload. After Run 2, all the new prototype features were rated as decreasing workload, except for Group Tasking. After Run 9, however, the HTR Viewer and BDA Recommendation features were rated as increasing workload. Similarly, Run 2 comments were all positive, while Run 9 comments were generally negative. Again, changes in personnel and run conditions may contribute to the reported workload differences between Runs 2 and Run 9. However, some new features were consistently rated as work reducers, particularly the AGM, New Alerts and Quick Fire features.

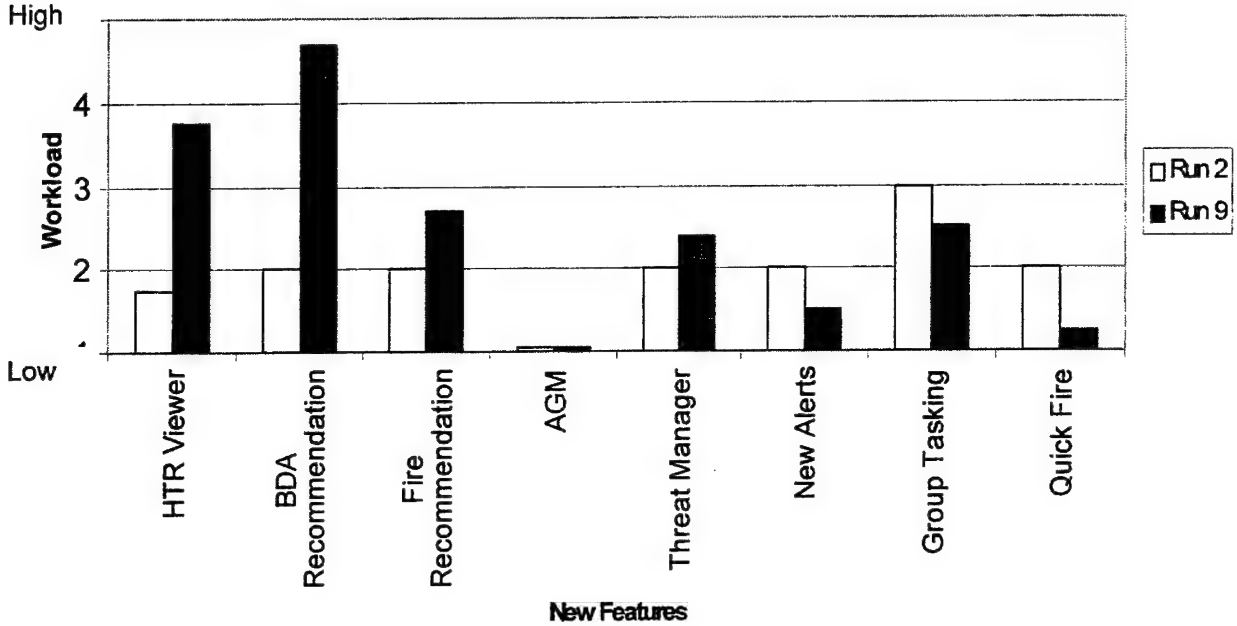

Figure 30. New C^2 Prototype Features Impact on Command Group Workload.
Scale Values: 1 = Decreased Greatly, 3 = No Change, 5 = Increased Greatly.

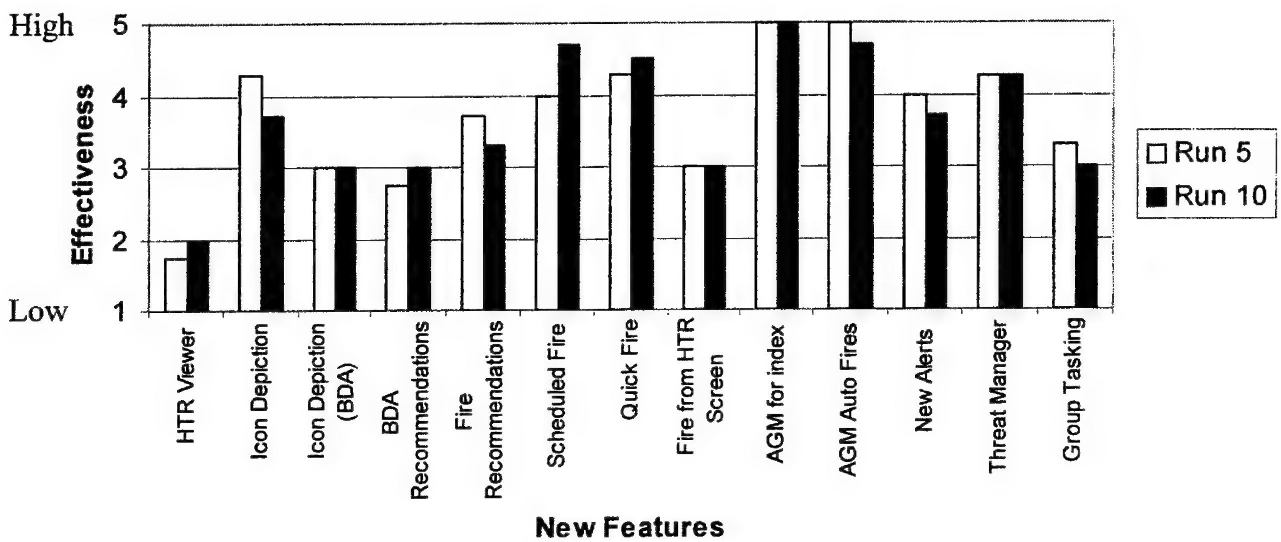

Figure 31. Mean ratings of Effectiveness of New Features Across Duty Positions.
Scale Values: 1 = Very Ineffective, 3 = Neutral, 5 = Very Effective

New C^2 Prototype Features Effectiveness. Figure 31 provides a summary of the findings on effectiveness of the new C^2 prototype features averaged across all players for Run 5 and Run 10. After Run 5, five of the thirteen new features were rated at or above "Effective" and two features were rated as "Very Effective" (AGM for Threat Index/Priority and Auto Fires).

However, the HTR Viewer and BDA Recommendations features were rated below "Neutral." After Run 10, most features were given similar ratings by the players.

C^2 Prototype Support of Command and Control. Figure 32 provides summary results on the average effectiveness of the C^2 prototype in support key command and control tasks. The results indicated that the C^2 prototype effectively supported nearly all of the tasks examined. However, the prototype was rated as less than "Effective" for Move Ground Assets, Map Display Manipulation, and particularly Battle Damage Assessment.

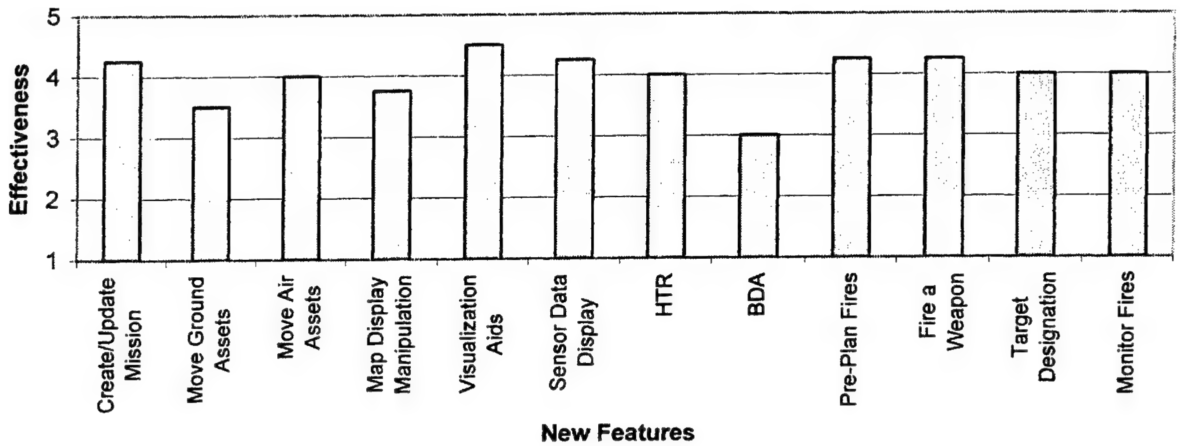

Figure 32. Mean ratings of Effectiveness of C^2 Prototype Across Duty Positions by C^2 tasks. Scale Values: 1 = Very Ineffective, 3 = Neutral, 5 = Very Effective; Run 8.

Teamwork Skills. Selected examples of effective and ineffective teamwork skills based on the command group responses to the C^2 Teamwork Skills questionnaire are provided below:

Communication:

- Effective: Screen sharing provides clear and accurate information exchange.
- Ineffective: Unsynchronized air and ground reconnaissance.

Coordination:

- Effective: Team coordinates work with synchronization matrix, AGM, group overwatch and follow. The UGS fired by Effects, but locations determined by Battlespace Manager.
- Ineffective: Focusing resources. The frontage of 30 km is too large. We spend more time reacting to the enemy than making him react to us. Some auto fires are not coordinated with manual fires, results in double taps of targets.

Performance Monitoring and Feedback:

- Effective: Commander can view everything a team member is doing and give feedback. Good cross talk within the C^2Vehicle during planning and execution. Team does a good job

of providing information to Battlespace Manager on targets engaged and which ones were hit. Team needs to monitor any continued movement of targets.
- Ineffective: Problems if each team member just worries about his task in isolation.

Shared Situational Awareness:

- Effective: Screen sharing provides 100% correct shared situational awareness.
- Ineffective: Screens can crash. Team members can become too focused on one particular area of the battle.

C^2 Decision Making. Selected examples of command and control decisions made and the support provided by C^2 prototype based on the command group responses to the C^2 Decision Making questionnaire identified are provided below:

Commander:

- Decisions: When to begin the attack and cross line of departure (LD), when and where to pursue the attack.
- Supporting C^2 prototype features: SA (situational awareness) map display is the key, the visual information is intuitive and informative, also Battlefield Assistant and Task Manager.

Battlespace Manager:
- Decisions: Route selection, system to select for engagements, BDA.
- Supporting C^2 prototype features: Auto Route Generation, Quick Fire button, Round Recommendation, Chaser rounds, HTR/Enemy Intelligence window.

Information Manager:

- Decisions: Focus the intelligence collection plan, template every position and COA.
- Supporting C^2 prototype features: Easy to task sensor, but sensor server is unreliable. The C^2 prototype allows for easy templating throughout planning and execution. Need toggle to turn off template on other screens to improve actual SA.

Effects Manager:

- Decisions: Configuration of Netfires load, weapon selection for targets of opportunity, best system to engage a type of target for automated fires, redirect LAMs for location of orbit or attack mode.
- Supporting C^2 prototype features: Netfires window boxes allow configuring number of rounds for PAM, LAM, UGS. Recommended Fires and AGM help decide best weapons to pair with targets at long, medium, and near distances. Right mouse click on LAM, open Redirect window, click on target, assign attack mission or new LAM orbit point.

Human Systems Integration. Results by function indicated low workload on basic C^2 functions, with all functions rated on the average near the level of "Low Workload" ("3" on the workload scale). The See function was rated highest in workload (Mean = 3.4), then Strike

(Mean = 3.1), Move (Mean = 2.6) and Plan (Mean = 2.3). However, results by task indicated higher workload for several tasks where the average rating ranged from "Task Attention Compromised ("4") to "Reduced Attention ("5"). These higher workload tasks included three See related tasks: Interpreting Sensor Data, Collecting Picture Data, and Interpreting Picture Data; and two Strike tasks: Designate Target and Battle Damage Assessment.

Results on prototype usability were generally positive. Battle Damage Assessment was the only task that was ranked by the majority of the players as being both illogical/inconsistent, and taking too many steps to complete. Most tasks were rated "Easy" or "Somewhat Easy" to perform. The three tasks rated as "Borderline" by at least one player with respect to ease of performance were: Visualizing Past and Future Threat Positions, Visualizing Missile Trajectory and Intended Target, and Determining What Entity Detected the Threat Target.

Table 17 provides a summary of the results on default settings for the C^2 prototype. Player feedback in the form of "No Change" and "Recommended Change" are included in this table for the seven default settings listed in the questionnaire and for the "Other" category. This feedback should help designers improve the default settings of the C^2 prototype.

Table 17

Recommendations for changes to CSE/C^2 Prototype default settings

Default Duty Position	Recommended Change
Search Radius (LAM/PAM)	
No Change	
Should out of range ammunition be an option?	
No Change	
When out of a type of ammunition, should it continue to be the default or even an option?	
Effects Manager	Would be nice to see more than one recommended fire option.
Should friendly entities be a default for weapons?	
Battlespace Manager	Should not be an option in any targeting cue.
Commander	(No written recommendation for improvement)
Should picture adjustments be saved for later viewing by you or a different person?	
Commander	Yes
Battlespace Manager	Different person.
Information Manager	(No written recommendation for improvement)
Should your tailored workstation be saved when the system crashes?	
Commander	Yes
Battlespace Manager	Yes
Information Manager	Yes, first 30 seconds used to redraw map and settings.
Should graphics such as the NAIs and phaselines be click/drag active during execution phase?	
Commander	Yes
Battlespace	Lock them down! When they move during execution, it is a pain.
Others	
Information Manager: *Need to put the toggles back for enemy units (by state).* *Need to add toggles for weapons (PAM, LAM, hits).* *Need different graphics for screen clarity.*	

Note: If a command group player is omitted under a question, he recommended no change to the default setting.

Training. Training at the individual level was substantially improved for Experiment 3. A formal training program was developed and provided for individual training. This training was intentionally not duty position specific, but rather designed to provide the cross-duty skills required to operate the C^2 prototype for any of the four primary command group duty positions. In addition, administrative guidance "fenced" the training room to minimize disruptions from visitors and observers. Observation of the training sessions was supported by teleporting the sessions to other rooms, particularly the AAR room. Training shortcomings included inadequate collective training and a neglect of plan training. Training issues and recommendations are examined in the Conclusions section.

Conclusions

This section provides concluding assessments concerning the method and results related to Human Functions Assessment for Experiment 3 of the FCS C^2 program. First, conclusions are provided on the results and measurement methods for Verbal Interactions and Human-Computer Interactions. Next, more general conclusions that include results on Subjective Measures as well as the results on objective verbal and HCI behaviors are provided on the following topics: workload, training, automated measures, and human-system integration. In closing, a brief set of sustain and improve recommendations are provided for future research efforts.

Verbal Interactions

Several method limitations with respect to the analysis of verbal communications for Experiment 1 and 2 were identified, and at least partially addressed for Experiment 3. Method refinements included the addition of two additional categories for characterizing verbal communications: Valence and Command Considerations. More successful method refinements from Experiment 2 were used again in Experiment 3. Particularly, communications were coded into much smaller chunks to better ensure that each chunk more precisely represented a unitary and discrete communication. As a result, the range of inter-rater agreement achieved in coding verbal communications from Experiment 2, ranging from a low of .86 for the Factor category to highs of .99 for Source, was noteworthy. A similar approach to chunking was used for Experiment 3. High inter-rater agreement suggests the verbal communication coding scheme provided a reliable method for assessing command and control communications that might be useful in a wider range of FCS research and development efforts.

Overall, the verbal data from the execution phase produced patterns generally consistent with Experiments 1 and 2. The relative distribution of communications by Source, Function, Type and METT-TC Factor were highly similar across Experiments 2 and 3. Verbal data from the planning phase provided some interesting differences in the pattern of communication during execution. Despite the preliminary nature of the planning data, verbalizations from the planning phase provide useful indicators for gauging execution performance and improving the training of future command groups.

Verbal results from the *execution* phases provide a useful basis for understanding command and control processes in FCS type organizations. Verbal interaction was an almost continuous activity during each of the execution phases analyzed for Experiment 3, as it was for

Experiment 2. This pattern of steady verbalization occurred in the context of (a) the command group's access to a visually rich and timely battlefield depiction on their C^2 prototypes, and (b) ongoing interactions with their C^2 prototypes to command and control a predominantly robotic force. A concluding hypothesis is that the level of verbal communication in a command and control organization increases as the level of visually based data/information increases.

Clearly, the verbal communications of the command group serve multiple functions, including the C^2 functions documented in the Results section. Most importantly, verbalization appears to be the command group's method of choice for transforming *data into information.* Although future C^2 systems are expected to help commanders visualize the battlefield, verbal communications may still be required to collaboratively process, filter and interpret the data visually displayed into meaningful information. The steady flow of verbalizations underscores its importance for command and control coordination and collaboration even when advanced multi-mode technologies are employed. In sum, the command group's vocalized efforts to transform data into information mirrors the evolving doctrine of FCS that states battle command must transform "See First" into "Understand First."

More specific functions of verbal communications were indicated by the dominance of Share and Ask vocalizations. Share and Ask communication, respectively disclosed the collaborative nature of the command group's work, and a fair degree of uncertainty about their upcoming battlefield situations. Moreover, almost 80% of Enemy related communications concerned Location or BDA, with approximately equal amounts of discussion devoted to each. This pattern of Enemy related communications underscored the command group's collaborative and balanced efforts to "find and fix" Enemy elements.

Valence ratings helped capture the affective meaning conveyed by command group communications, more specifically positive and negative status information on the accomplishment of C^2 functions. Status information is essential to maintaining command and control in dynamic situations, and a basis for evaluating alternatives and making decisions. Valence also highlights problems that require attention. Negatively valenced communications provide useful diagnostic information on the limitations of the C^2 prototype and the operational setting. Efforts by the FCS C^2 program's Technical Team to refine the C^2 prototype and operational environment should attend to the problems the command group was experiencing as negatively rated verbalizations occurred.

Command Considerations were introduced for Experiment 3 to provide a more explicit link between thought and action, particularly action in the form of the command group's verbal interaction. How do the verbal behaviors of the participants relate to the cognitive processes required for battle command? As expected, given the experienced and expert command group participants, communications related to all nine Command Considerations were found. Two near exceptions were the low frequencies tabulated for Coordinate (create synergistic effects) and Assets (use all assets available). However, with experienced command groups, the coordinated use of all assets may be more implied than explicit. To the extent that the Command Considerations identified are key to battle command, comparisons with less experienced participants may prove more discriminating and useful. The ARI notes that the Comprehensive Report by ARI across FCS C^2 Experiments 1-4 will include a section on less experienced

command groups based on the FCS C^2 Summer Study with Cadets. Command Considerations may also prove useful in setting "baseline" expectations for command group training.

Results on *planning* provide useful, if preliminary, data on the important but largely neglected topic of planning for small unit FCS command and control. The ARI's decision to focus on planning was based on two primary considerations, as noted. The evolving concept of FCS command and control stresses the requirement for more effective and collaborative planning methods before and during execution. By design, the planning process and products prior to execution provide the basis for planning changes during execution, sometimes referred to as dynamic re-planning. Planning for a manned and *robotic* force, such as the Unit Cell, requires substantial changes in the planning process and products required for execution.

The preliminary nature of the planning results was stressed due to method shortcomings. Even the findings of reduced verbalizations during planning was due, in part, to player absence from the C^2 vehicle and failure to wear headsets consistently during the planning phase. Notably, the most interesting explanation for less talk may be *actual* differences in the communication requirements for planning versus execution. However, method shortcomings should be eliminated or at least reduced, before more firm conclusions on actual differences are reached.

Verbal interactions disclosed that Plan related topics were the most frequently discussed C^2Function. This result was not surprising, but quite different from execution communications. Similarly, many planning communications related to the Mission factor in METT-TC, indicating the players' concerns with mission goals and plans prior to execution. As during execution, Share and Ask type communications dominated planning indicating the collaborative nature of the command group's work, and uncertainty about the upcoming battlefield situation.

A "hot" topic during planning was the C^2 prototype (IT/CSE), particularly concerns and questions about how to correctly input operational plans. Players expressed uncertainty about what could be done with the C^2 prototype during planning versus during execution. Given Runs 10 and 11 were the last runs during Experiment 3, this topic of communication suggests that training was inadequate, particularly in support of planning.

In sum, to improve the value of the planning data obtained, ARI recommends that future efforts modify the experimental design to overcome the data collection shortcomings and curtailed planning activities noted above. However, refinements to training and human performance assessment are also needed to better see, understand and improve small command group planning for FCS.

Human-Computer Interactions

Overall, many of the research goals for HCI analysis were at least partially achieved. Based on ARI's understanding of the new features developed in the C^2 prototype for Experiment 3, and a review of all Run 10 video recordings, the HCI rating scheme developed for Experiment 2 was revised and expanded (see Figure 1). The evaluation framework for HCI remained structured to basic C^2 Functions (Plan, See, Move, Strike) and Sub-Functions. However, the number of HCI tasks identified increased from 53 to 83 to reflect the new features added to the

C^2 prototype for Experiment 3, and ARI's focus on documenting the HCI tasks performed during planning as well as execution.

Results identified new HCI tasks, task allocation arrangements across the command group, and even task allocation across the dual screens provided at individual workstations. In general, the results provided quantitative estimates of command group workload and the impact of automation on key C^2 functions and tasks during execution and planning. Overall, the results provide an emerging empirical basis for reallocation of tasks among the command group, and between the command group and increasingly automated C^2 systems.

Results provided precise indicators of needed improvements in the design of future C^2 systems to minimize workload and training requirements. For example, the procedure of taking multiple UAV "snapshot" pictures around templated targets yielded hundreds of useless target images that had to be reviewed. Similarly, automated features such as "auto recon" and route generation may relieve players of the routine task of entering route points. However, these same features raise the demand on players to more fully understand the decision rules and parameters designed into such features. During Run 10, the Shadow UAV "wandered off" toward enemy elements under auto recon and was inadvertently destroyed, a critical loss to the See First capability of the Unit Cell. This unintended consequence of high automation was due to information overload, too many useless images to view, and the lack of an effective human override to abort an automated routine in a timely manner.

Results from planning were at least partially successful. Particularly in identifying and documenting the frequency and duration of new tasks *unique* to planning with advanced C^2 prototypes and semi-automated forces. Planning for manned and *robotic* forces requires substantial change in the planning process and products required for execution. The results reported provide an interesting and important window for understanding the impact of FCS on the planning process of small command groups.

Again, ARI stresses that results on planning are incomplete and preliminary. Method recommendations were made for overcoming many of the planning shortcomings identified. First, the introduction of new missions on unfamiliar terrain would require more extensive planning and provide a more valid base for planning assessment. Second, more representative play of upper and lower echelons would raise the requirement for more formal and tractable planning procedures and products.

Workload

The higher levels of automation provided by a host of new features in the C^2 prototype for Experiment 3 were designed to at least partially automate key C^2 functions, particularly See, Move, and Strike. Many of these new features were well received by the participants. By their own account, the new automation features reduced workload for some tasks and increased the effectiveness of the command group and the Unit Cell. New features consistently rated as work reducers, included the Attack Guidance Matrix, New Alerts and Quick Fire features.

Automation is a double-edged sword, however, particularly during the early development cycle that characterized the new C^2 prototype features. At times, automation failed to perform as expected. At other times, automation performed in unexpected and detrimental ways. All too often, lack of trust in automation was an issue that seriously compromised human and unit performance.

Across the series of FCS C^2 experiments, overall average workload ratings have varied substantially: Means = 57.6, 61.2 and 48.9 for Experiments 1-3, respectively. The increase in Experiment 2 workload appeared due to changes made in C^2 prototype functionality and task allocation between experiments, as discussed in ARI's Interim Report for Experiment 2. During Experiment 2, the command group players were required to perform additional tasks, such as Effects, Human Target Recognition (HTR), and Battle Damage Assessment (BDA). Concerns that sensors provided unrealistically good information during Experiment 1, resulted in sensor degradations and a shift in the allocation of HTR and BDA tasks to the command group players during Experiment 2. In contrast, the See and Move focus of Experiment 1, allocated Strike and supporting effects tasks largely to higher echelons. During Experiment 3, the lower levels of perceived workload seem to reflect the higher levels of automation provided by new C^2 prototype features in support of See, Move, and Strike functions.

Notably, multiple reviews of same images during Experiment 3 were substantially less than during Experiment 2. Credit for this workload reduction goes in large to design changes in the C^2 prototype to provide an audit trail on images reviewed and by whom. This is the type of information processing assistance readily performed by computers to improve the efficiency and effectiveness of command group performance, particularly for human intensive tasks such as HTR and BDA.

Many of the workload problems associated with automation and experienced during Experiment 3 were expected. Such problems are typical with advanced technology insertions in high-risk and dynamic operational settings. For command and control, automation issues and problems of particular concern include: allocation, authority, autonomy and awareness (Lickteig, et al., 2002). Such human performance issues must be addressed and resolved before FCS concepts are transformed into viable constructs and solutions.

Training

Training at the individual level was substantially improved for Experiment 3. A formal training program was developed and provided for individual training. This training was intentionally not duty position specific, but rather designed to provide the cross-duty skills required to operate the C^2 prototype for any of the four primary command group duty positions. In addition, administrators "fenced" the training room to minimize disruptions from visitors and observers. Observation of the training sessions was supported by teleporting the sessions to other rooms, particularly the AAR room.

During Experiment 3, automation from new features increased the training challenge substantially at individual and collective levels. Examples of training shortcomings include the command group's tendency to "double tap" numerous targets. A lack of familiarity with and

feedback on the AGM system caused players to engage targets manually due to doubts about when and if targets would be effectively engaged by the AGM. Similarly, a lack of experience in monitoring multiple air assets and anticipating auto recon consequences resulted in loss of Shadow and Micro-UAV sensors.

Training shortcomings included inadequate collective training and neglect of planning. Three training improvements are recommended for collective training: (1) structured, practical exercises directed at collaboration within the Unit Cell and with other echelons, (2) exercises embedded in operational conditions, and (3) exercises directed at planning, not just execution. Understanding C^2 prototype complexities for planning—especially input requirements and consequences for automated See, Move and Strike functions—requires structured training directed specifically on their use with clear operational feedback. Refresher training on "old" features is also required. As indicated by comments such as "Where did the Intervisibility button go?"

A final conclusion is that the training challenge associated with more advanced, and particularly automated, technology must not be underestimated. The ARI's conclusion is that automation will increase the training challenge substantially at individual and collective levels. ARI's concerns about training issues as a result of automation apply to the C^2 prototype evolving under the FCS C^2 program, and to the "objective" C^2 system that will be fielded for FCS.

Automated Measures

The introduction of automated measures of human-computer interaction during Experiment 3 sharpened the program's focus on human performance measurement. Prior experiments had relied too heavily on subjective measures *about* performance including questionnaires and interviews rather than direct measures *of* performance, particularly for human performance assessment.

As a result, for Experiments 1 and 2 ARI's objective measures of human performance were based primarily on manual reduction of audio and video behaviors from recorded runs. The video records were used to conduct a relatively laborious analysis of human-computer interactions, namely command group participant interactions with the C^2 prototype, as documented in ARI's Interim Report for Experiment 2.

Overall, results on development and validation of automated measures were meager but promising. Only 3 of the 23 automated measures requested by ARI for HCI analysis were developed for Experiment 3. Two of the three automated measures developed for Experiment 3 were at least partially validated. Discrepancies identified for Images Requested/Viewed and Create Ground/Air Route should be resolved with collaboration by behavioral and technical experts. Additional development, refinement and validation are clearly needed to develop a useful set of automated measures to support training, evaluation and C^2 system design.

Automated performance measures are required to support training, evaluation and C^2 system design (Unit of Action Maneuver Battle Laboratory, 2002). This requirement applies to the FCS C^2 prototype, and to all future C^2 systems. Manual video data reduction of command

and control performance can only examine a fraction of the data potentially available from C^2 research and training efforts. In contrast, automated logs of human-computer interactions provide efficient and effective measures of command and control performance.

The efficiency of automated measures equates to quick and inexpensive. It includes the ability to adjust the range and selection of data to include the performance of any or all C^2 users at any or all times during an operational exercise. The effectiveness of automated measures equates to increased scope and precision in the collection of C^2 performance data. It includes more meaningful measures by automatically correlating C^2 performance with the battlefield situation in which it occurred.

During the AARs for Experiments 2 and 3 logs of *simulation* and *system* activity were used to provide immediate feedback on issues such as shots and kills. However, no logs on *human* activity were available despite serious concerns about workload and task allocation. One example of the human performance data needed for Experiment 2 AARs was workload data on image manipulation. How much time was spent manipulating picture images? How many times was the *same* picture opened and manipulated by *different* people? Automated measures of human-computer interactions could readily answer these and many other human performance issues in the area of command and control.

Overall, automated human performance data can address the question "How well did the command group perform the C^2 function?" as opposed to simply asking, "Who won the battle?" For the FCS C^2 program's commander-centered focus, such data are more valuable in assessing the prototype C^2 system than loss-exchange ratios and other battle outcome measures. Battle outcomes are contingent on manipulations of force size and capability, but C^2 performance is contingent on C^2 system design decisions.

Human-System Integration

From a human performance perspective, the C^2 interface for FCS will be a primary point, or means, of interaction between commanders and Soldiers, and between commanders/Soldiers and robotic entities. One criterion for assessing the adequacy of a C^2 interface is that it enables thought and action in a manner the user chooses (Rasmussen & Pejtersen, 1995). It should also provide a common operational picture and, particularly for FCS, a common mode of interaction for command and control of manned and robotic forces.

A final criterion noted here is that a C^2 interface must ensure automated functions are *not too transparent* or invisible, as they were at times during Experiment 3. The phrase "transparent to the user" often connotes a good thing. However, the user must also be able to render visible the underlying processes and actions associated with the automated features provided by a C^2 interface. If not, the complexity and uncertainty induced by mediating layers of technology can severely restrict the ability of humans to detect unexpected system difficulties and consequences, or even provide informed consent (Olson & Sarter, 2001).

Developing the "objective" C^2 interface required for FCS is a key challenge that will require iterative use and refinement. A preliminary conclusion by ARI's research team for FCS

C^2 is that this program is developing a cutting-edge C^2 interface for FCS. At present, this interface reflects the sustained (nearly two year) use and refinement by an exceptional set of command group participants. Effective interface design requires sustained user-based input, not a bunch of guys/gals sitting around a table (BOGSAT) or a drive-by user jury.

Admittedly, much interface refinement work remains that should be performed in future efforts. However, key features that distinguish the FCS C^2 interface from many other fielded and prototype C^2 interfaces are:

- Value grounded on *sustained* use and refinement by expert users.
- Provides an increasingly effective interface for command and control of *robotic* entities.
- Integrates C^2 of *human and robotic* forces versus "swivel-chair" integration.

Recommendations for Future FCS C^2 Experiments

The research environment and iterative experimental design of the FCS C^2 program affords an excellent venue for exploring new approaches to command and control. The human performance findings from Experiment 1-3 serve as important benchmarks, and the lessons learned provide direction for future FCS efforts. However, method improvements are needed to help meet the Army's future command and control requirements.

The ultimate value of a research and development program is determined as much by the resources spent on evaluation, as the resources spent on simulation. And the ultimate value of a C^2 system is determined not by the technology per se, but by shaping technology to complement human performance. Some key sustain and improve recommendations are bulleted below for future FCS C^2 experiments:

- Maintain Medium, High, and Too High Complexity levels to determine performance limits.
- Maintain Deliberate Practice design to ground findings on proficient performance.
- Capitalize on the requirement for and value of automated measures of human performance.
- Add novel missions and terrain to broaden the spectrum of operations, including planning.
- Improve methods to develop and disseminate findings across doctrine, organizations, training, materiel, leader development, personnel, and facilities (DOTMLPF).
- Improve methods for identifying and codifying new approaches to command and control by documenting the C^2 lessons learned during After Action Reviews.
- Ensure technology complements human performance.

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Appendix A

List of Acronyms

AAR	After Action Review
ADA	Air Defense Artillery
ATD	Automatic Target Detection
AFRU	Armored Forces Research Unit
AGM	Attack Guidance Matrix
ARI-Knox	U.S. Army Research Institute for the Behavioral and Social Sciences at Fort Knox
ARL	Army Research Laboratory
AQ	Area Query
BDA	Battle Damage Assessment
BOGSAT	Bunch of Guys/Gals Sitting Around a Table
C^2	Command and Control
C^2V	Command and Control Vehicle
C^4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CECOM	U.S. Army Communications-Electronics Command
CEP	Circular Error Probable
COA	Course of Action
CSE	Commander's Support Environment
DARPA	Defense Advanced Research Projects Agency
DCSOPS&T	Deputy Chief of Staff for Operations and Training
DOTMLPF	Doctrine, Organizations, Training, Materiel, Leader Development, Personnel, and Facilities
DVO	Direct Vision Optics
FBC	Future Battlefield Conditions
FCS	Future Combat Systems
FIFV	Future Infantry Fighting Vehicle
GCM	Graphic Control Measure
GSR	Ground Surveillance Radar
HCI	Human-Computer Interaction
HUD	Heads Up Display
HTR	Human Target Recognition
IFV	Infantry Fighting Vehicle
IPT	Integrated Product Team
IR	Infra Red

ISR	Intelligence, Surveillance, Reconnaissance
IT/CSE	Information Technology/Commander's Support Environment
IUGS	Internetted Unattended Ground Service
LAM	Loitering Attack Missile/Munitions
LD	Line of Departure
LOS	Line of Sight
METT-TC	Mission, Enemy, Terrain, Troops Available—Time and Civilians
MOP	Measure of Performance
MPERM	Multipurpose Extended Range Munition
MTI	Moving Target Indicator
NAI	Named Areas of Interest
NASA	National Aeronautics and Space Administration
Netfire	Network Fire
NLOS	Non Line of Sight
NTC	National Training Center
OPCON	Operational Control
PAM	Precision Attack Missile
PM	Program Manager
RDEC	Research and Development Center
ROTC	Reserve Officers' Training Corps
SA	Situation Awareness
SAR	Synthetic Aperture Radar
SD	Standard Deviation
STO	Science and Technology Objective
TK	Track
TRADOC	Training and Doctrine Command
TQ	Target Query
TTP	Tactics Techniques and Procedures
TLX	Task Load Index
UAV	Unmanned Aerial Vehicle
UGS	Unattended Ground Sensor

Appendix B

Verbal Communication Rating Scheme: Definitions and Examples

For each chunk select

SOURCE (for each verbal chunk select one and only one Source code)

1	Within Cell (Black)	Cell = 4 C^2 prototype operators.
2	Cell <-> Blue (Team)	
3	Cell <-> White (Higher)	
4	Cell<->Subordinate	Subordinate (includes C^2Vehicle gunner & driver).
5	Blue<-> White	
6	More than 2-way (e.g., Cell<->White<->Blue)	Only to be used in cases where more than 2 elements involved in SAME conversation.
7	Other	E.g., to technical support people.

FUNCTION (for each verbal chunk select one and only one Function code)

1	See	Detect or identify enemy or friendly positions, or significant terrain aspects (not BDA).
2	Plan	Interpret data, predict enemy COA, generate own COA
3	Move	Manage/monitor/control asset movement.
4	Strike	Manage/monitor/control lethal/nonlethal effects.
5	BDA	See for purposes of BDA.
6	Other	None of the above.

VALENCE (for each verbal chuck select one and only one Valence code)

	1	0	-1
See	Ability to See	Neutral/inconclusive	Inability to See
Plan	Plan Working	Neutral/inconclusive	Plan not Working
Move	Ability to Move	Neutral/inconclusive	Inability to Move
Strike	Ability to Strike	Neutral/inconclusive	Inability to Strike
BDA	Ability to Confirm Kill	Neutral/inconclusive	Inability to Confirm Kill
Other	Other Function Achieved	Neutral/inconclusive	Other Function not Allowed

TYPE (for each verbal chunk select one and only one Type code)

1	Share. Verbalization about what is seen or known.
2	Action. Verbalization about what speaker is doing at the moment, verbalization with action such as fire or move. (Not the decision process. Not actions as I see, monitor, track, etc. Not describing someone else's actions.)
3	Direction. Order, command, delegation of responsibility.
4	Ask. Verbalization begins with request for information, confirmation, assistance, or assets and ends with either informational answer or no response, with little or no discussion. Not rhetorical questions.
5	Process. Infer, synthesize, fuse, understand, and turn data into information without consequent decision or direction. Can start with Share, Action, or Ask.
6	Decide. Like Process, but in addition, includes a verbalized decision or plan.
7	Other.

FACTOR (for each verbal chunk select one and only one Factor code)

MISSION	
1	Original Plan: Concerning mission goals and plans prior to execute phase.
2	Dynamic Planning: Tactical re-planning during the execute phase in response to changing events and available assets. Must have stated COA (course of action). Changes from Original Plan.
3	Situational Understanding. Integration/summary of current situation involving multiple factors, but without stated COA.
ENEMY:	
4	Location: Sensor hit(s) – locate enemy positions.
5	Identification: Identify targets – identify nature of enemy target.
6	Disposition: Probable enemy COA, strategy, or tactics.
7	BDA: Battle Damage Assessment – cell seeks/discusses feedback on damage they inflict on enemy.
TERRAIN	
8	When terrain is the prime focus (e.g., Can we travel over that kind of terrain? We should go this way because it will provide cover). Example: "Moving to low ground." Not simply map locations (e.g., not, sensor hit north of the wall).
TROOPS and Assets (Soldiers, Equipment, Vehicles) Friendly only.	
9	Location Status: Position report/assessment.
10	Movement Status: Mobility report/assessment (includes fuel).
11	See Status: Sensor report/assessment.
12	Strike Status: Firepower report/assessment (includes # of remaining missiles)
13	Communications/network functionality (radio, internet, or other; cell to outside cell, including semi-autonomous sensors).
14	Information management systems: C^2 prototype user interface tools.

15	Survivability Concern: Asset in danger.
16	Survivability Move: defensive move to remove asset from immediate danger.
17	Loss/Casualty: Asset destroyed (catastrophic hit).
18	Move Action: Move/Manage/Maneuver [Active, Not position report] Excluding Survivability Move; Also See Terrain.
19	Strike Action Lethal: Launch/fire/deploy with intent to destroy (includes LAMs)
20	Strike Action Nonlethal: Launch/fire/deploy (could include unarmed sensors, propaganda, smoke, jamming of enemy, etc.).
21	Training (Soldier training, mission rehearsal).
22	Other-- having to do with troops or assets but none of the above.
TIME	
23	When time is the prime focus (e.g., how much time something will take, how much time is available, order of priority, synchronization of actions).
CIVILIANS	
24	Any issues regarding how to deal with civilians: avoiding, provisioning, protecting, etc. Not mere sensor hits of civilians, unless first time mentioned.
Other	
25	Other (e.g., humor, personal, leadership, morale).

Coding rules of thumb for Verbal Communication Rating Scheme:

Type:

Rationale: Share, Action, and Direction are meant to be relatively short interactions, without a lot of discussion. Chunks including a lot of discussion or consideration of multiple aspects of situation should be either Process or Decide. These are distinguished by whether there is a definite conclusion reached (Decide) or not (Process).

1. When in doubt between Share and Action, choose Share.
2. When in doubt between Share and Process or Decide choose Process or Decide (as appropriate).
3. When in doubt between Ask and Process or Decide choose Process or Decide (as appropriate).
4. Rhetorical questions or questions following an announcement should **not** be coded as Ask. (e.g., I have a mover, do you see it?—should be Share).
5. You have to pay attention to both the beginning and end of a chunk. If contains a verbalized decision, plan, or direction, it is Direction or Decide, regardless of how it begins. Distinguish Direction and Decide by whether it is preceded by some discussion (Direction is not; Direction stands alone. Decision is preceded by relevant discussion). For example, a sensor hit followed by a direction to fire should be classed as a(type: direction/subject: lethal effects, not type: share/subject: sensor hit. (as per example below).

- We've ID the other mover wheel coming out of hidden valley is a URL.
- Dave take that URL with a PAM.

Subject:

Rationale: Choose the major subject of the chunk. Consider, what information is the speaker trying to convey?

1. Choose Dynamic Replanning or Situation Understanding when the conversation contains discussion of multiple assets. Use Dynamic Replanning when it does include a course of action (here's what we should do). Use Situation Understanding when it does not include a course of action or plan, but only summarized the current situation. If chunk contains discussion of only a single asset, choose the appropriate category related to that type of asset or action.
2. Sometimes judgment will be required. In these cases try to imagine what is the subject the speaker is trying to convey? (e.g., "Darya found by Roboscout" Context will usually help. I would tend to code this as Sensor hit, especially if it is the first time the hit was mentioned. On the other hand, a preceding question regarding which sensor system detected the Darya, would make the main information conveyed by the utterance Sensors…" Who found the Darya? Darya found by Roboscout").
3. When the Type is scored as "Ask," and there is ambiguity as to Subject, focus on what kind of information the asker is after.

System:

1. If more than one asset is mentioned, give more than one system code. Note the existence of categories such as Other, Unspecified, or Not Applicable.

- Other—asset is mentioned, but is not one of the choices.
- Unspecified—clearly talking about one of the assets but you can't tell which (e.g., you know it is a lethal effect, but you don't know which one).

Not Applicable—a system is simply not applicable to the subject discussed in the chunk.

Appendix C

Examples of Chunks from the 10 Most Frequent Source-Type-Factor Profiles

Source	Type	Factor	% of Run 10	% of Run 11
Within-Cell	Share	Enemy Location	2.7	6.6
Example:	There's one Garm there. Okay, I've got it. … One NL2, and a combined arms platoon at 460.			
Within-Cell	Share	Enemy Disposition	1.3	4.9
Example:	Cause if we're going to have a combined armed reserves out here. Right. And that's fine. Actually, though. Just for future reference, a tank platoon in his order of the battle is three platoons. A tank platoon in our area of course, is four tanks. Yeah, is four tanks, okay. I'll put them in right down here. This is where I think they'll be. Alright, that's good. Alright, so that means that he's got a company down there, and a company up yonder. Yonder.			
Within-Cell	Share	C^2 Prototype	2.7	4.9
Example:	Just screwed up…NAIs. Uh-oh. The one all the way up there? Yeah. No, no. Delete that one. I don't need that one. I don't need those up there. I was going to delete them. I was just reassembling them around. There we go. Is there anything else you would like for me to delete up top? I was going to get those. I can get those? You can take those Garms if you want to. Alright. I've got them. You want more? Nah, that should work. Just enough to get us a picture.			
Within-Cell	Share	Other	0	6.6
Example:	And, how are we doing, guys? Gals? Anybody? Women? Children? I say—You know what I say? I say that we just throw the game on, whether the reds are ready or not. It should be like a surprise attack.			
Within-Cell	Ask	Mission*	6.7	4.9
Example:	We got two Purga locations? Ok we got 2 Purga locations there in the Northeast. Right down there I put PAMs on each one of those then I followed them up with LAMs to see if we can get some movement. I am reluctant to put more PAMs out there because of the…I've got additional LAMS. Check. Roger.			

Within-Cell	Ask	Enemy Location	5.3	3.3
Example:	Tank alpha 22 is a tank? The very bottom of the plot? Check. He's confirmed, they gave us 6 digit grids, so I am sure there is something there.			
Within-Cell	Process	Enemy Disposition	5.3	0
Example:	He thinks we are coming there, he obviously thinks we are coming in the south			
Within-Cell	Decide	Mission	6.7	0
Example:	Then that means we have to make a conscious effort to use the Intelligence, Surveillance, Reconnaissance (ISR) Assets. Oh, absolutely. Not shoot everything in the North. Correct, I agree. Let him start moving, let him come to us.			
Cell-Blue	Ask	Communications	1.3	4.9
Example:	And, Blue 6. Black 6. Radio check. Over. Blue 6. Black 6. Radio check. Over.			
Other	Other	Other	0	4.9
Example:	How you doing? Are you Jack? Yes, I am. This is Paul. Hey, Paul. How you doing?			
Total			32.0	41.0

Appendix D

HCI Rating Scheme with Description of Rating Categories

100 PLAN (Describe Tactical Situation, Concerns, and Future Activities, Request Information.)

110. Create/Update a Mission and COA
    111. Create Overlay Graphics and Map Annotations
    112. Place platforms on the map (friendly and threat template)
    113. Rehearse the Plan
    114. Execute the Plan
    115. Point on Map Using Cursor/Indicate an Area
    116. Move icons (vehicle or GCM) on map using drag/drop
    117. Modify overlay graphics

120. Alerts
    121. Create Alerts

200 MOVE (Manage/Monitor Control Asset Movement)

210. Move Ground Assets (Start = First blue line appear, Stop = Click OK)
    211. Create routes (clicking map locations to create blue route line)
    212. Start, Halt or Resume a platform
    213. Edit an existing route
    214. Delete all tasks (from execution window)
    215. Place UGS
    216. Overwatch
    217. Generate Route
    218. Recon an Area

220. Move Air Assets (Start = First blue line appear, Stop = Click OK)
    221. Create Routes (either by creating a direct route or by selecting targets to recon)
    222. Delete all tasks (from execution window)
    223. Edit an existing route
    224. Recon an Area/Auto Recon Targets
    225. Task to Hover

230. Group Follow
    231. Create Ground Follow
    232. Create Air Follow
    233. Create Mixed (Ground and Air) Follow

300 SEE (Manage Map and Sensor Data Display)

310. Manipulate Map
    311. Zoom Map (either arrow or magnification tools)
    312. Scroll Map

320. Use Visualization Aids
    321. Toggle Range Fans
    322. Plot Intervisibility
    323. Measure Distance
    324. Display on Heads Up
    325. Select/Change Windows, State View, or window area for display

(increasing/decreasing a window area such as Asset or Alert window for better viewing)

326. Change GCM Settings (Declutter Map – Includes Hide Impacted Missiles)
327. Move Visual Reference Points (red cross used by higher. Expect to eventually include in analysis all who manipulate information during runs on the C^2 prototype)

330. Display Sensor Data
  331. Display Target Catalog (open this spreadsheet window, is it normally open?)
  332. Query Enemy (cursor over enemy icons to read properties information)
  333. Query Friendly (cursor over friendly icons to read properties information)
  334. Query Area (cursor over area to read properties information)
  335. Change Sensor (UAV, Shadow, Roboscout etc.)
  336. Toggle sensor fans
  337. Acknowledge Alert Window
  338. Highlight Target on Map using Target Catalog
  339. Take Manual UAV Picture

340. Recognize Targets (Start = HTR window open, Stop = Close HTR window)
  341. Display target images (through Alert Window, clicking the picture icon on map, select window, etc.)
  342. Refine image (zoom, pan, brightness, etc.)
  343. Change Map Icons to reflect target status (i.e., Garm, Draega, Bus, etc.)
  344. Remove templated targets (State View selection)
  345. Select recon target by clicking icon
  346. Select recon target by select window

350. Assess Battle Damage (Start = HTR window open, Stop = Close HTR window)
  351. Display target images (through Alert window, clicking the picture icon on map, select window, etc.)
  352. Refine image (zoom, pan, brightness, etc.)
  353. Change Map Icons to reflect target status (i.e. targeted, suspected, dead, etc.
  354. Assign unit to BDA through BDA Recommendations
  355. Acknowledge Alert (Ground hit/Unit hit)

360. Summarize Situational Awareness
  361. Open Threat Management Window
  362. Query Enemy (Unit Viewer)
  363. Track Unit (Unit Viewer)
  364. Query Enemy (Unit Viewer)
  365. Update/Change information displayed in Battlefield Assistant (e.g., EFire, FFire)

400 STRIKE (Distribute Indirect and Direct Effects Over a Set of Targets)

410. New Features
  411. Recommend Fire Unit
  412. Open Quick Fire
  413. Engage from Enemy Intel Window

420. Target Designation
  421. Designate by Icon Click
  422. Designate by Menu Selection
  423. Designate by "Select" Window

430. Fire Weapon System
  431. Fire Netfire LAM

432. Reassign LAM Final Attack Command (right click on LAM icon and reassign to attack)
433. Fire Netfire PAM
434. Fire LOS
435. Fire C^2Vehicle (Gun and Javelin)
436. Fire FW CARRIER (IFV)
437. Fire Dismount Javelin
438. Delete all scheduled fire tasks

440. Monitor Fires Execution
441. Query LAM (cursor over LAM icons to read properties information)
442. Query PAM (cursor over PAM icons to read properties information)

450. Scheduled Fires
451. Set Minutes to Fire
452. Set Delimiters

460. Attack Guidance Matrix
461. Create AGM
462. Select target category
463. Select Autofire threat level
464. Set Weapon Priorities
465. Edit Roles
466. Adjust threat index settings

500 OTHER MANUAL ACTS

510 General
511. Reboot system (Start = Fatal Error, Stop = C^2 Prototype full restart)

Appendix E

Example of Human-Computer Interaction Rating Codes
(Effects Manager's Right Screen Run 10)

Duty Position: Effects Screen: 4 Right Run: 10

Run Time (minutes)		Code	Description
Start Time	Stop Time		Typical configuration of screen = 50% map, 25 % asset window, and 25 % execution window.
0 00 25		325	Increase Map Window
0 00 30		312	Scroll Map
0 00 57		325	Increase Map Window
0 01 08		312	Scroll Map
0 01 22		311	Zoom Map
0 01 26		312	Scroll Map
0 01 38		333	Friendly Query (FQ)
0 19 45		312	Scroll Map
0 19 49		312	Scroll Map
0 19 53		334	Area Query (AQ)
0 19 56		333	FQ
0 20 14		421	Select Target by Clicking Icon
0 20 28		433	Fire PAM
0 24 18		333	FQ
0 24 33		423	Select target by "select" window
0 24 46		433	Fire PAM
0 25 00		332	Target Query (TQ)
0 25 01		334	AQ
0 26 42		338	Highlight Enemy by Target Window
0 26 47		312	Scroll Map
1 04 11		312	Scroll Map
1 04 32		332	TQ
1 04 36		332	TQ
1 04 50		332	TQ
1 05 22		412	Quick Fire Open
1 05 25		421	Select target by clicking icon
1 05 28		433	Fire PAM
1 06 07		332	TQ
1 06 31		441	LQ
1 06 33		441	LQ
1 06 41		442	PQ
1 06 47		334	AQ
1 06 49		312	Scroll Map
1 06 54		312	Scroll Map

Run Time (minutes)		Code	Description
Start Time	Stop Time		
1 07 41		311	Zoom Map
1 09 06		311	Zoom Map
1 09 37		334	AQ
1 09 45		311	Zoom Map
1 09 47		332	TQ
1 16 03		441	LQ
1 16 06		332	TQ
1 17 00		332	TQ
1 17 12		412	Quick Fire Open
1 17 16		421	Select target by clicking icon
1 17 20		433	Fire LAM
1 23 40			End of Execution

Appendix F

Frequency of Human-Computer Interactions by Function,
Sub-Function, HCI Task and Duty Position, Run 10 Execution

Function *Sub-Function* HCI task	Commander Freq.	Battlespace Manager Freq.	Information Manager Freq.	Effects Manager Freq.
Move	---	28	27	---
Move Ground Assets	---	28	---	---
Create routes	---	11	---	---
Start, halt or resume a platform	---	4	---	---
Edit and existing route	---	5	---	---
Delete all tasks	---	2	---	---
Create Overwatch Task	---	1	---	---
Generate Route	---	5	---	---
Move Air Assets	---	---	27	---
Create routes	---	---	18	---
Delete all tasks	---	---	1	---
Edit an existing route	---	---	5	---
Task UAV to hover	---	---	3	---
See	101	189	304	188
Manipulate Map	11	18	6	91
Zoom map	2	6	5	42
Scroll map	9	12	1	49
Use Visualization Tools	6	29	26	12
Toggle Range fans	2	1	---	---
Measure distance	---	2	---	---
Display heads up	1	4	6	1
Select/change windows/state View	2	14	16	3
Change GCM settings	1	8	4	8
Display Sensor Data	45	66	102	62
Display target catalog	---	1	1	---
Query enemy	23	20	24	41
Query friendly	2	22	26	7
Query area	14	14	49	13
Change sensor	---	5	1	---
Toggle sensor fans	6	4	1	---
Highlight Target by Catalog	---	---	---	1
Function *Sub-Function* HCI task	Commander	Battlespace Manager	Information Manager	Effects Manager

Recognize Targets	1	2	37	1
Display target images	1	---	5	---
Refine image	---	---	3	---
Change icons to reflect type	---	---	6	---
Remove templated targets	---	---	1	1
Recon by clicking icon	---	---	13	---
Recon by select window	---	2	9	---
*Assess Battle Damage**	9	42	132	4
Display target images	8	24	67	4
Refine image	1	18	61	---
Change map icons to reflect target status	---		4	---
Situation Awareness	29	32	1	18
Open threat management	1	---	---	---
Query enemy (Unit Viewer)	6	14	---	11
Track unit (Unit Viewer)	15	1	---	2
Query friendly (Unit Viewer)	7	17	---	5
Change Information Given	---	---	1	---
Strike	4	90	7	103
New Features	---	1	---	19
Open Quick Fire	---	1	---	19
Designate Target	---	41	1	28
Designate by icon click	---	9	1	21
Designate by menu selection	---	---	---	---
Designate by select window	---	32	---	7
Execute Fires	---	46	1	32
Fire LAM	---	---	---	3
Reassign Lam	---	---	1	6
Fire PAM	---	3	---	23
Fire LOS	---	40	---	---
Fire IFV	---	3	---	---
Monitor Fires	4	2	5	24
Query LAM	4	1	2	17
Query PAM	---	1	3	7
Other	---	2	---	---
Reboot System	---	2	---	---
Total	105	309	338	291

Appendix G

Summary of Command Group HCI Performance Across Time, Run 10 Execution

00-10 Players concern themselves with tailoring their workstations (e.g., zoom and scroll), AGM makes most fires and pre-plan fires emerge. All four players exhibit concerns about situational awareness (e.g., target, area and friendly queries) and perform mostly See related tasks.

10-20 Players continue to tailor their workstations. Players heighten their situational awareness of the battlefield, and perform many tasks related to battle damage assessment. Few fires are performed and arial sensors are moved for reconnaissance. Most tasks performed are in support of the See function.

20-30 Players continue to tailor their workstations and continue situational awareness at a decreased level. Many tasks are centered around battle damage assessment and an increased level of fires are performed. Most tasks performed are in support of the See function. No movement takes place in this section.

30-40 Players greatly reduce their tasks related to tailoring their workstations. Increased situational awareness occurs during this time period as well as a decrease in executed fires. Many tasks are still associated with battle damage assessment and the majority of all tasks performed are related to the See function.

40-50 Ground and arial movements commence at a higher level in this section due to the loss of the Shadow. No tasks are performed in relation to tailoring of the workstation, and situational awareness and battle damage assessment tasks remain at the previous level. Few fires are performed as most tasks are related to the See function.

50-60 Movement continues due to the loss of the Shadow, and players display an increase in situational awareness tasks. Battle damage assessment remains a priority and both the Battlespace Manager and Effects Manager greatly increase their executed fires. A majority of the tasks support the See function, but during there is a distinct increase in Strike tasks performed during this period.

60-70 Movement occurs for ground units toward the end of this period due to enemy artillery and reconnaissance. Players are once again greatly concerned with tailoring their workstations and situational awareness. Many tasks are performed in support of human target recognition and battle damage assessment. Fires remain at a heightened level. Most tasks are performed in support of the See function.

70-80 Movement continues due to artillery fire and reconnaissance. Levels of tailoring the workstation, situational awareness and battle damage assessment remain high. Fires are again increased by the Effects Manager. The majority of all tasks support the See function.

80-84 During the final stages of the run, players mostly concern themselves with situational awareness and battle damage assessment with a few executed fires. Most tasks represent the See function.

Appendix H

Subjective Measures

Workload and Performance – Task Load Index Rating Scales
C^2 Prototype/CSE Effectiveness in Support of C^2 Functions and METT-TC Factors
Skill Proficiency
C^2 Prototype/CSE Features Impact on Workload
C^2 Prototype/CSE New Features Effectiveness
C^2 Prototype/CSE Effectiveness in Support of Command and Control
C^2 Teamwork Skills
C^2 Decision Making
Human Systems Integration Questionnaire
Training

Task Load Index Rating Scales

Task or Mission Segment: ______________________________

Please rate the task or mission segment by putting a mark on each of the six scales at the point which matches your experience.

Mental Demand

Very Low — Very High

(HOW MENTALLY DEMANDING WAS THE TASK?)

Physical Demand

Very Low — Very High

(HOW PHYSICALLY DEMANDING WAS THE TASK?)

Temporal Demand

Very Low — Very High

(HOW HURRIED OR RUSHED WAS THE PACE OF THE TASK?)

Performance

Failure — Perfect

(HOW SUCCESSFUL WERE YOU IN ACCOMPLISHING WHAT YOU WERE ASKED TO DO?)

Effort

Very Low — Very High

(HOW HARD DID YOU HAVE TO WORK TO ACCOMPLISH YOUR LEVEL OF PERFORMANCE?)

Frustration

Very Low — Very High

(HOW DISCOURAGED, IRRITATED OR ANNOYED WERE YOU?)

C^2 FUNCTIONS AND METT-TC SURVEY

Part 2. CSE Effectiveness

Duty Position ______________ Date ___________ Run # _____

Across all Runs, how effective was the CSE in support of C^2 Functions and METT-TC Factors?

C^2 Functions

	NA	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
1. PLAN: Create Mission/COA, tools (range fans, intervisibility).	NA	1	2	3	4	5
2. MOVE: Create routes, move, halt, retask ground and air assets.	NA	1	2	3	4	5
3. SEE: Target data, Human Target Recognition, sensor data).	NA	1	2	3	4	5
4. SHOOT: Plan and Execute fires, check resources, BDA	NA	1	2	3	4	5

1. PLAN: Create Mission/COA, tools (range fans, intervisibility). NA 1 2 3 4 5
   Comments: ____

2. MOVE: Create routes, move, halt, retask ground and air assets. NA 1 2 3 4 5
   Comments: ____

3. SEE: Target data, Human Target Recognition, sensor data). NA 1 2 3 4 5
   Comments: ____

4. SHOOT: Plan and Execute fires, check resources, BDA NA 1 2 3 4 5
   Comments: ____

METT-TC Factors

1. Mission: Operations Plan, Dynamic Planning, Coord w/ Higher NA 1 2 3 4 5
   Comments: ____

2. Enemy: Activities, Composition, Probable COA NA 1 2 3 4 5
   Comments: ____

3. Terrain: Key Terrain, Avenues, Observation Lines, Fields of fire. NA 1 2 3 4 5
   Comments: ____

4. Troops & Assets: Training adequacy, Vehicles, Sensors, Weapons NA 1 2 3 4 5
   Comments: ____

5. Time: Maneuver, Coord., Asset task time (ex. time of flight) NA 1 2 3 4 5
   Comments: ____

6. Civilians: Identifying, tracking, avoiding, protection. NA 1 2 3 4 5
   Comments: ____

AFTER RUN SURVEY

Part 2. Skill Proficiency

Duty Position ________________ Date ________ Run # ___________________

At this time, how proficient are you as an individual and as a collective team?

Proficiency

1	2	3	4	5	6	7	8	9
Extremely Low	Very Low	Low	Below Average	Average	Above Average	High	Very High	Extremely High

	Rating (1-9)
Individual	
1. How technically proficient are you at using the CSE to perform your C2 Cell individual tasks? Comments: ____	
2. How tactically proficient are you at serving in your C2 Cell duty position. Comments: ____	
Team	
1. How technically proficient is the C2 Cell Team in using the CSE to perform collective tasks? Comments: ____	
2. How technically proficient is the C2 Cell Team in directing the actions of robotic assets? Comments: ____	
3. How tactically proficient is the C2 Cell Team in communicating (gathering/ sharing information)? Comments: ____	
4. How tactically proficient is the C2 Cell Team in making key decisions? Comments: ____	

CSE FEATURES SURVEY

Part 2. New CSE Features Workload

Duty Position ______________ Date ___________ Run # _______

Across all Runs, how did these CSE features impact overall workload?

CSE Automated Features

		Increased Greatly	Increased Slightly	No Change	Decreased Slightly	Decreased Greatly
1. Enemy Intel/Human Target Recognition (HTR) Viewer	NA	1	2	3	4	5
2. Battle Damage Assessment Recommendation (recon)	NA	1	2	3	4	5
3. Fire Recommendation	NA	1	2	3	4	5
4. Attack Guidance Matrix (AGM)	NA	1	2	3	4	5
5. Threat Manager	NA	1	2	3	4	5
6. New alerts (e.g., PAM/LAM feedback, self-protection)	NA	1	2	3	4	5
7. Group Tasking (Overwatch, Follow)	NA	1	2	3	4	5
8. Quick Fire	NA	1	2	3	4	5

1. Enemy Intel/Human Target Recognition (HTR) Viewer
   Comments: ____

2. Battle Damage Assessment Recommendation (recon)
   Comments: ____

3. Fire Recommendation
   Comments: ____

4. Attack Guidance Matrix (AGM)
   Comments: ____

5. Threat Manager
   Comments: ____

6. New alerts (e.g., PAM/LAM feedback, self-protection)
   Comments: ____

7. Group Tasking (Overwatch, Follow)
   Comments: ____

8. Quick Fire
   Comments: ____

CSE SURVEY

Part 2. CSE New Features Effectiveness

Duty Position ________________ Date ____________ Run # _______

Across all Runs, how effective were these CSE features?

	NA	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
1. Enemy Intel/HTR Viewer Comments: ______________________________	NA	1	2	3	4	5
2. Icon depiction of Engage States/Fire States Comments: ______________________________	NA	1	2	3	4	5
3. Icon depiction of BDA Indicators (ties with Enemy Intel screen) Comments: ______________________________	NA	1	2	3	4	5
4. BDA Recommendations (recon) Comments: ______________________________	NA	1	2	3	4	5
5. Fire Recommendations Comments: ______________________________	NA	1	2	3	4	5
6. Scheduled Fire Comments: ______________________________	NA	1	2	3	4	5
7. Quick Fire Comments: ______________________________	NA	1	2	3	4	5
8. Fire from HTR/BDA Enemy Intel Screen Comments: ______________________________	NA	1	2	3	4	5
9. Attack Guidance Matrix (AGM) for threat index/priority Comments: ______________________________	NA	1	2	3	4	5
10. Attack Guidance Matrix (AGM) for auto fires Comments: ______________________________	NA	1	2	3	4	5
11. New alerts (e.g., LAM/PAM feedback, self-protection) Comments: ______________________________	NA	1	2	3	4	5
12. Threat Manager Comments: ______________________________	NA	1	2	3	4	5
13. Group Tasking (Overwatch, Follow) Comments: ______________________________	NA	1	2	3	4	5

AFTER RUN SURVEY

Part 2. CSE Support of C2 Tasks

Duty Position _______________ Date __________ Run # _______

How effective was the CSE in support of C2 tasks?

		Very Ineffective	Ineffective	Neutral	Effective	Very Effective
1. Create/Update a Mission and COA (Create graphics, rehearse plan)	NA	1	2	3	4	5
2. Move Ground Assets (Create and edit routes)	NA	1	2	3	4	5
3. Move Air Assets (Create and edit routes)	NA	1	2	3	4	5
4. Map Display Manipulation (Zoom, Scroll)	NA	1	2	3	4	5
5. Use Visualization Aids (Range fans, head up display, change GCM)	NA	1	2	3	4	5
6. Sensor Data Display (Create alerts, bring up target properties)	NA	1	2	3	4	5
7. Human Target Recognition (Display/refine image, change icons)	NA	1	2	3	4	5
8. Battle Damage Assessment (Display/refine image, change icons)	NA	1	2	3	4	5
9. Pre-Plan Fires/Execute Pre-Plan Fires (AGM, Auto fires)	NA	1	2	3	4	5
10. Fire a Weapon System (Netfires, LOS, C2V, FW Carrier, Javelin)	NA	1	2	3	4	5
11. Target Designation (Icon click, Menu select)	NA	1	2	3	4	5
12. Monitor Fires Execution (Cursor over LAM, PAM)	NA	1	2	3	4	5

Each item is followed by: Comments: ______________________________

AFTER RUN SURVEY

Part 2. C2 Teamwork Skills
Duty Position ____________________ Date ______________ Run # ________

Please provide an example of Effective and Ineffective performance for each of the four C2 activities listed below.

1. Communication: Information clearly and accurately exchanged between team members, the ability to clarify or acknowledge the receipt of information.

Effective ____

____

Ineffective ____

____

2. Coordination: Team resources, activities, and responses are organized to ensure tasks are integrated, synchronized, and completed within established time constraints.

Effective ____

____

Ineffective ____

____

3. Performance monitoring and feedback: Team members monitor the performance of teammates, give, seek, and receive task-clarifying feedback, and offer advice.

Effective ____

____

Ineffective ____

____

4. Shared situational awareness: Team members share a common model of the team's internal and external environment, maintain a common understanding of the situation, apply appropriate task strategies.

Effective ____

____

Ineffective ____

____

AFTER RUN SURVEY

Part 2. C2 Decision Making

Duty Position ____________________ Date ______________ Run # _________

Please briefly describe several IMPORTANT DECISIONS you had to make during this Run, and identify CSE features that support the decision where applicable.

1. Decision: ____

____

CSE Features: ____

____

2. Decision: ____

____

CSE Features: ____

____

3. Decision: ____

____

CSE Features: ____

____

4. Decision: ____

____

CSE Features: ____

____

Name ______________________ Duty Position ___________________ Date _________

Human Systems Integration Questionnaire

This questionnaire asks for your feedback on how well the CSE/C^2 Prototype system supports human information requirements for battle command.

1. Using the workload description rating scale, provide a rating of your perceived workload by writing the corresponding number in the "Rating" column for each of the following *functions* (plan, move, see, strike) and related tasks from 1 to 10. Please add any other key tasks that impact workload by writing them in the cells labeled "Others?" below.

Workload

1	2	3	4	5	6	7	8	9	10
Insignificant	Very Low	Low	Task Attention Compromised	Reduced Attention	Little Spare Capacity	High	Very High	Extremely High	Task Abandoned

Function and Task	Rating (1-10)	Recommended Improvement to Reduce Workload
Plan		
Position Icons on the Map		
Rehearse the Plan		
Mission/Task Change		
Others?		
Move		
Ground Asset		
Air Asset		
Position Unmanned Ground Sensors (UGS)		
Task Sensor to Recon		
Others?		

WORKLOAD

1	2	3	4	5	6	7	8	9	10
Insignificant	Very Low	Low	Task Attention Compromised	Reduced Attention	Little Spare Capacity	High	Very High	Extremely High	Task Abandoned

Function/Task	Rating (1-10)	Recommended Improvement to Reduce Workload
See		
Map Manipulation (eg. Zoom)		
Using Heads Up Display		
Altering Workstation Layout		
Creating Alerts		
Collecting Sensor Data		
Interpreting Sensor Data		
Collecting Picture Data		
Interpreting Picture Data		
Others?		
Strike		
Detect Targets		
Recognize Targets		
Classify Targets		
Identify Targets		
Designate Target		
Fire NETFIRES		
Fire Line of Sight (LOS)		
Battle Damage Assessment (BDA)		
Others?		

2. Please check Yes or No for each item in column 2a (task clarity) and 2b (task complication) below.

a. Are there any tasks that are not logical or consistent?	b. Did any tasks require too many steps to complete?
Share information on Heads Up Display Yes___ No___	Share information on Heads Up Display Yes___ No___
Create routes Yes___ No___	Create routes Yes___ No___
Edit existing tasks Yes___ No___	Edit existing tasks Yes___ No___
Measure distance Yes___ No___	Measure distance Yes___ No___
Tailor workstation (window size and log out) Yes___ No___	Tailor workstation (window size and log out) Yes___ No___
Changing sensor used Yes___ No___	Changing sensor used Yes___ No___
Human Target Recognition (HTR) Yes___ No___	Human Target Recognition (HTR) Yes___ No___
Target designation Yes___ No___	Target designation Yes___ No___
Allocating search radius (LAM/PAM) Yes___ No___	Allocating search radius (LAM/PAM) Yes___ No___
Fire NETFIRES Yes___ No___	Fire NETFIRES Yes___ No___
Fire LOS Yes___ No___	Fire LOS Yes___ No___
Fire Javelin Yes___ No___	Fire Javelin Yes___ No___
Battle Damage Assessment (BDA) Yes___ No___	Battle Damage Assessment (BDA) Yes___ No___

3. Please place a checkmark in the appropriate box that corresponds to the amount of trouble you experienced viewing the following display characteristics.

Display Characteristics	Never Have Trouble	Seldom Have Trouble	Occasionally Have Trouble	Frequently Have Trouble
Legibility of text				
Contrast between symbols and background				
Brightness of displays				
Size of displays				
Color of symbols				
Text on displays				

4. Please place a checkmark in the appropriate box that corresponds to the amount of difficulty/ease in accomplishing the following tasks.

Symbology Characteristics	Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult
Ease of distinguishing between friendly and threat icons					
Ease of distinguishing between moving and stationary threat icons					
Ease of visualizing past and future threat positions					
Ease of distinguishing between LAM/PAM missile icons					
Ease of visualizing missile trajectory and intended target					
Ease of determining what entity detected the threat target					
Ease of understanding navigation symbology (waypoints, hazards, etc.)					

5. Are there any menus or tasks that are either too difficult to navigate or take too much time that they complicate your performance? Please circle: **YES** **NO**

Please explain:

____

____

____

____

____

6. Are there any items in the CSE/ C^2 Prototype improperly or confusingly labeled? Please circle: **YES** **NO**

Please explain:

____

____

____

____

____

7. Please place a checkmark in the appropriate box that corresponds to how easy is it to read/understand the data provided in the following CSE/C^2 Prototype windows.

	Very Easy	Easy	Borderline	Difficult	Very Difficult
Map Window					
Mission Workspace (Table of Organization and Equipment)					
Execution Window (mission timeline)					
Resource Availability					
Asset Window					
Alert Ticker Window					
Alert Editor					
Target Catalog					
Battlefield Assistant					
Graphic Control Measures (GCM) Window					
Collection Management (CM) Planner					

8. Are there any CSE/C^2 Prototype default settings that you would recommend a change? If there is no change that you recommend for a given default, please place a check mark in the "No Change" column for that default. The following blank cells are for your suggestions on other defaults that need adjustments.

Default	No Change	Recommended Change
Search Radius for LAM/PAM		
Should out of range ammo be an option		
When out of a type of ammo, should it continue to be the default or even an option		
Should friendly entities be a default for weapons (RoboScout, UGS)		
Should picture adjustments be saved for later viewing by you or a different person		
Should your tailored settings and user preferences be saved and automatically loaded when the system crashes		
Graphics such as the Named Area of Interests (NAIs) and phaselines being click/drag active during execution phase		
Others?		

Training Survey

Name ____________________ Duty Position ________________ Date ___________

Training Adequacy

How adequate was the **individual** training provided to prepare you for your duty position in the C2 cell, in terms of content coverage and time spent?

CONTENT: ____

____

TIME: ____

____

How adequate was the **collective** training provided to prepare the members of the C2 cell to work as a team, in terms of content coverage and time spent?

CONTENT: ____

____

TIME: ____

____